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THE ILEOCOLIC ARTERY AND THE APPENDIX

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Introduction

APPENDICITIS is as common as ever and the terminal ileum, whether in resections, ileostomy, or the fashioning of an isolated loop, receives more attention now than formerly. No apology is offered for a new study of the anatomy of this important corner of the abdomen.

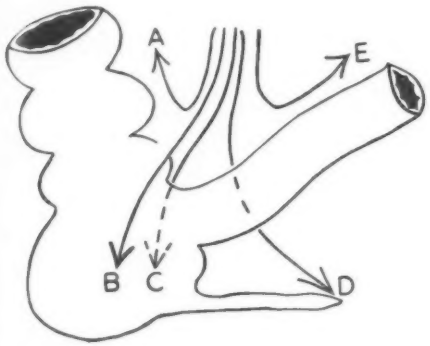

FIG. I. Final branches of ileocolic artery. These branches show, in their names, the organs supplied by the ileocolic artery — colic (A), anterior caecal (B), posterior caecal (C), appendical (D), ileal (E).

This paper describes the ileocolic artery, its branches, and the appendical and nearby peritoneum, as removed *en bloc* with terminal ileum and proximal colon at 50 post-mortems. Some additional observations are derived from the author's experience of over 800 appendicectomies.

Examination and simple naked-eye dissection of the autopsy specimens suggest revision of previous descriptions and point several surgical lessons, to be found under the following headings:

1. The ileocolic artery.
2. The appendical arteries.
3. The appendical mesentery (or mesoappendix).

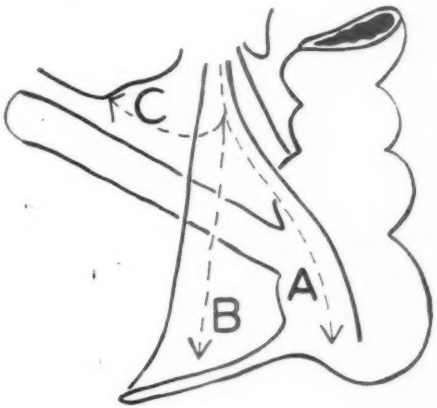

FIG. II. An example of variations in the final branches of the ileocolic artery. Here there is a duplicate posterior caecal artery (dotted line A) which gives off an appendical branch (B) and a further branch (C) anastomosing with the ileal artery.

1. *The ileocolic artery*

This vessel is clearly shown by Haller (1743) though for more realistic details of its terminal branches one has to wait for Cloquet's drawing (1828), faithfully imitated by Quain (1842). Cloquet's plate shows the ileocolic dividing into colic and ileocaecal branches, the appendical artery arising from the former (see below).

In these dissections, the following details were found:

(i) There are five final branches of the ileocolic artery, viz. (Fig. I)—

colic (ascending colic),
posterior caecal,
anterior caccal,
ileal,
appendical.

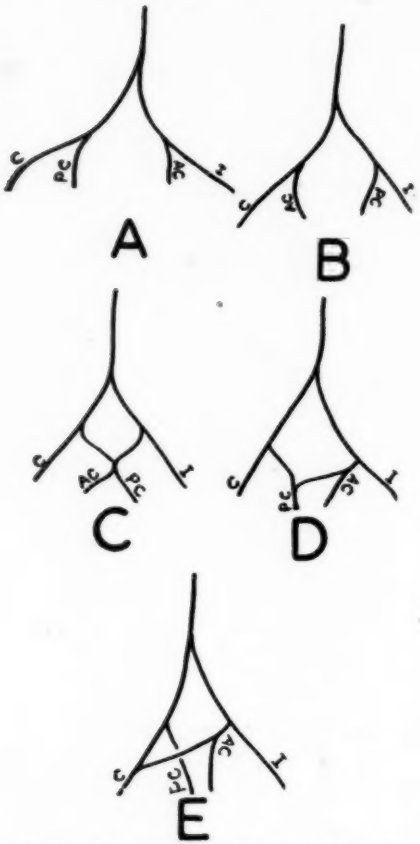

FIG. III. First pattern of division of the ileocolic artery as observed in these 50 dissections. In this, the commonest (18/50) and not previously described arrangement, the ileocolic artery bifurcates into caecocolic and ileocaecal divisions. A-E are variations observed within this pattern (see Table 1).

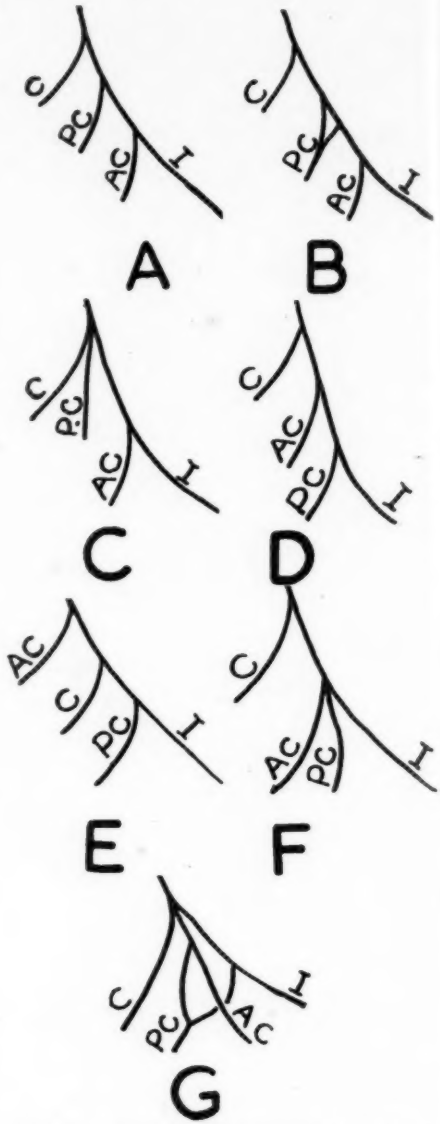

FIG. IV. Second pattern of division of the ileocolic artery. In 17/50 specimens the ileal was the last of separate branches. Of the variations seen (A-G), A is described as the commonest arrangement of the ileocolic artery in Buchanan's *Manual of Anatomy* (1949), and in Gray's *Anatomy* (1947).

(ii) Each may be doubled, or may anastomose with another, or may send branches to other parts. A simple example is shown in Fig. II.

(iii) If one ignores the appendical for the moment, these branches are found to come off the ileocolic in five ways (Table 1). Most usually (and not previously described) this

vessel divides into caeco-colic and ileocaecal stems, each having two branches (Fig. III). More often than not the caecal parts of each stem join to form a common caecal trunk or plexus, from which anterior and posterior caecal branches arise (Fig. IIIC). This bifurcation of the ileocolic is really more common than the numbers suggest, because in many cases included under other patterns the branch given off first (or last) is equal in size to the stem from which the others arise singly. Most of the cases in Pattern 4 and several in Pattern 2 are like this. Probably it would be more accurate to describe them as, for example, dividing into two stems, ileal and caeco-colic or colic and ileocaecal

TABLE 1

PATTERNS OF THE ILEOCOLIC ARTERY

Pattern	*Variant*	*Specimen Number*	*Totals*
1	A	11, 30, 48	3
	B	2, 9	2
	C	7, 8, 13, 15, 18, 23, 24, 37, 38, 39, 49	11
	D	46	1
	E	20	1
		Total:	18
2	A	1, 6, 19, 40, 41, 45	6
	B	3	1
	C	33, 44	2
	D	16, 21, 31, 35	4
	E	22, 27	2
	F	12	1
	G	43	1
		Total:	17
3	A	4, 10, 17, 28, 32, 50	6
	B	26, 29	2
	C	5	1
		Total:	9
4	A	34, 36	2
	B	47	1
	C	14	1
		Total:	4
5		42	1
		Total:	1
Unknown		25	1
		Total:	1

(Cloquet, 1828; Shah and Mubarikah Shah, 1946) than to say that all their branches arise separately from an ileocolic trunk. In the second pattern, all branches arise sparately from the main trunk, ileal last and colic (usually) first (Fig. IV). This is the arrangement described in Buchanan's *Manual of Anatomy*, 1949 (Fig. IVA). Note the obvious tendencies towards Pattern 1 in Fig. IVC.

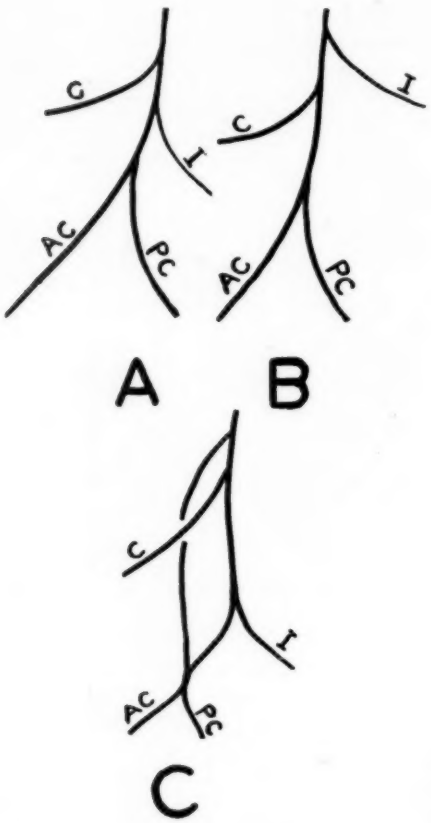

FIG. V. Third pattern of division of the ileocolic artery. In 9/50 specimens the ileocolic finally divided into anterior caecal and posterior caecal after giving off ileal and colic. A-C are the variations observed. A is described in Cunningham's *Text-book of Anatomy* (1951) as the commonest arrangement of the ileocolic artery.

Less often, the ileocolic divides finally into anterior and posterior caecal, after giving off colic and ileal. This is the third pattern (Fig. V) and Cunningham's *Text-book of Anatomy*, 1951, describes one of its variants (Fig. VA) as the commonest arrangement of the ileocolic. In fact it was found in six cases.

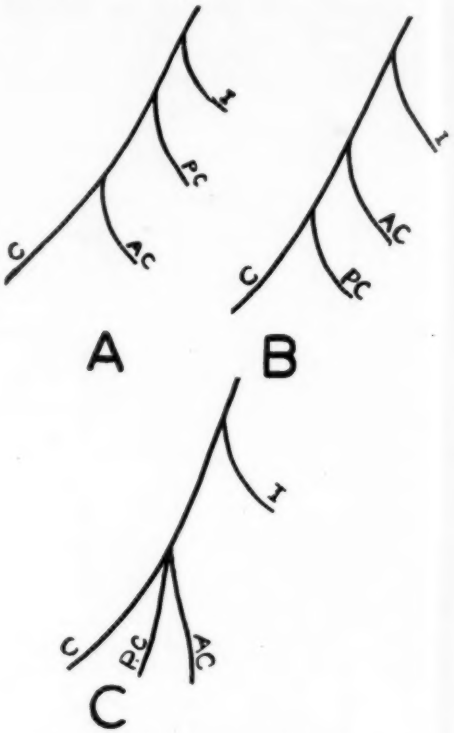

FIG. VI. Fourth pattern of division of the ileocolic artery. 4/50 specimens showed the ileal as first branch, the other separate branches varying as in A-C.

In the fourth pattern the ileal is the first, not the last, of separate branches, so that the direction of the axis of the trunk is the opposite of that found in Pattern 1. This arrangement is uncommon and has not been described before (Fig. VI).

That which Morris (1925) describes as usual, the trunk ending as ileal and colic, is rarest of all (Fig. VII).

(iv) In several cases the right colic artery clearly arose from the ileocolic (Haller, 1743; Cloquet, 1828; Steward and Rankin, 1933) but how often one cannot be sure from these specimens, where the ileocolic artery was often divided some distance from its origin.

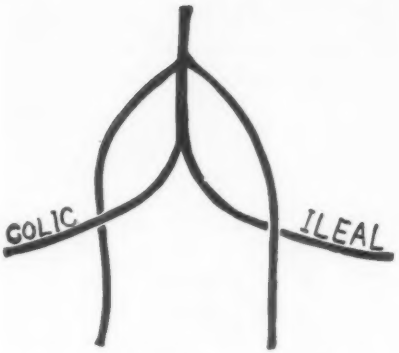

FIG. VII. Fifth pattern of division of the ileocolic artery. In one case only the ileocolic artery gave off anterior and posterior caecal branches before dividing into colic and ileal, though Morris' *Treatise on Anatomy* (1925) describes this as the commonest arrangement.

(v) The anterior caecal artery is usually in the free border of the superior ileocaecal fold (Treves, 1885), but not when it anastomoses with the ileal (Fig. VIII) when there is no fold (see below).

(vi) The branches of the posterior and anterior caecal arteries finally pierce the muscle coats of the bowel (Fig. IX) just medial to the posterior and anterior taeniae respectively (Edwards, 1939). But it is the posterior caecal, not the colic branch, which usually supplies the first few centimetres of ascending colon (Fig. XB) by branches running alternately on either side of the medial taenia. There is no anastomosis on the surface of the bowel between the branches of the caecal arteries, so one "cannot confidently expect one beneath the surface" (Sunderland, 1942).

(viii) The ileal branch of the ileocolic is nothing more than the continuation of that vessel or of one of its parts into the end of the superior mesenteric, and no one can tell its total field of supply. In 13 specimens additional small arteries from the ileocolic, ileocaecal, or ileal itself, ran to anastomose with the main arch joining ileal and superior mesenteric. Those from the ileal must be considered bifurcations of it, but those from the ileocolic and ileocaecal (2 specimens) must be regarded as additional ileal arteries (Fig. XA).

In almost half of these specimens (20/50) separate branches from the main ileal trunk or from a recurrent stem supplied the end of the small bowel (Fig. XI). In the remainder other vessels took part, usually the posterior caecal (14/30), but also the anterior caecal (9/30), the common caecal plexus (6/30), and even the appendical in one case. These additional arteries invariably formed an arcade with the ileal, as in the diagram (Fig. XII), but sometimes (7/30) the anastomosis was high up near the origin of the ileal and in one specimen the extra artery— from the anterior caecal — was entirely separate. In

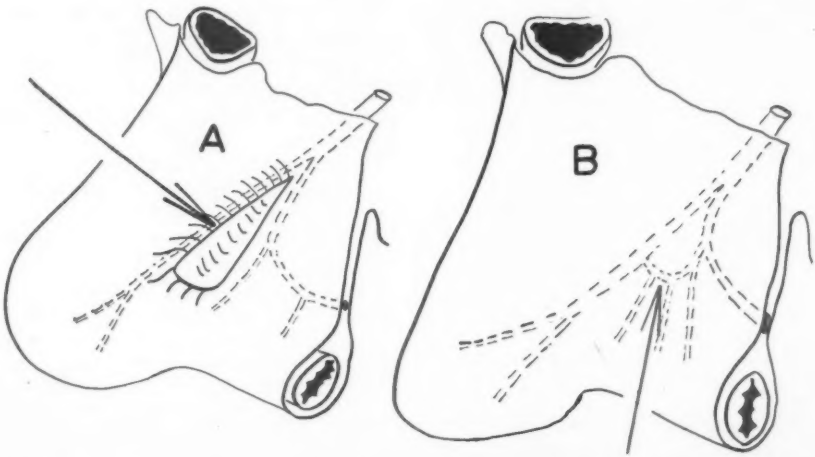

FIG. VIII. The superior ileocaecal fold. In A the fold (carrying the anterior caecal artery) is indicated by an arrow. In B an arrow indicates the anastomotic arch with the ileal, obliterating the fold.

5 specimens (17, 26, 30, 48 and 49) most of the terminal ileum seemed to be supplied by the additional vessel, in these cases arising from the anterior caecal.

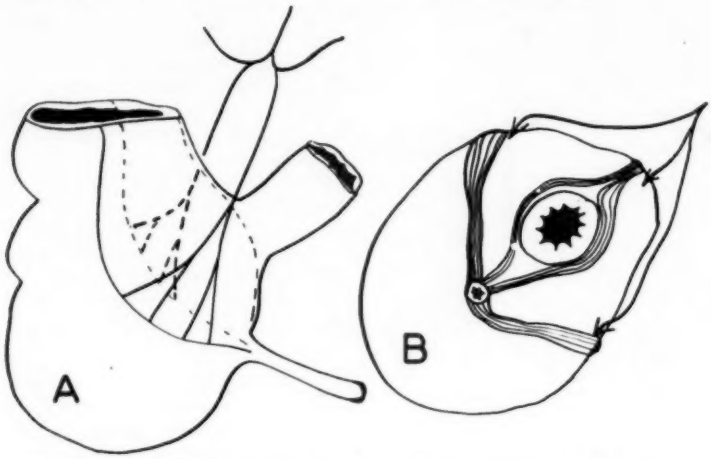

FIG. IX. Distribution of the caecal arteries. A is an anterior and B an infero-medial view of the anterior and posterior caecal arteries entering the bowel wall near the taeniae.

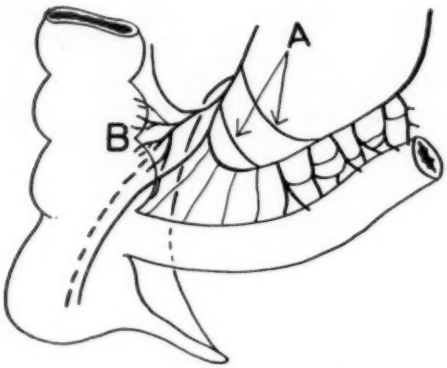

FIG. X. Additional ileal anastomotic arteries and arterial supply of proximal ascending colon. The arrows A indicate additional ileal arteries (found in 8/50 specimens), the upper one from the ileocolic, the lower from the ileocaecal. Branches of the posterior caecal artery are shown supplying the ascending colon (B).

In all cases the blood supply of the terminal ileum is meagre since:

1. The vessels are small and few;
2. multiple arcade formation does not begin for 4.5-8.5 cms. from the ileocaecal junction (Fig. XIII);

so for various reasons,

1. poor blood supply;
2. short mesentery;
3. proximity of branches of ileocolic artery in the terminal mesentery—

it seems unwise to divide the ileum in its last few centimetres whether ileostomy, anastomosis, or an isolated loop is planned (Fig. XIV). One method positively endangers the anterior caecal, particularly when that vessel anastomoses with the ileal (see above and Fig. XIVC), namely, division at the ileocaecal junction. There is, after all, no obvious intercaecal anastomosis on the bowel wall.

Before dividing the terminal ileum and its mesentery it is suggested that the surgeon should:

1. Look for multiple arcades; if fat obscures the view, divide the ileum at least 10.0 cms. (4 ins.) from the ileocaecal junction;
2. estimate the length of the mesentery; it may be too short to allow the ileum to be brought to the skin if ileostomy is intended, and there are no arcades in the terminal portion to allow safe mobilization by division of the main branches of the superior mesenteric artery in Roux fashion;
3. look for the superior ileocaecal fold. If there is none, and the caecum is to be left *in situ*, never divide the ileum

and its mesentery at the ileocaecal junction unless you can see and clearly avoid the anterior caecal artery.

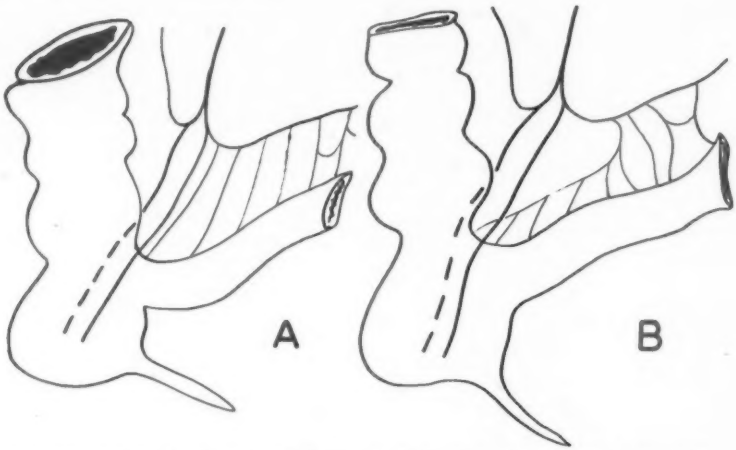

FIG. XI. Arterial supply of terminal ileum by ileal artery alone. In 20 specimens the ileal branch of ileocolic alone supplied the terminal few centimetres of ileum, by separate branches in 9 cases (A), and via a recurrent stem in 11 cases (B).

2. *The appendical artery*

Roughly speaking the present teaching about the appendical artery is:

(a) It is usually single (but see Seschachalam and Gorur, 1930);

(b) it arises low in the ileocolic pattern, e.g. from the posterior caecal;

(c) the artery gives off parallel branches running straight into the organ without further branching.

These statements are not confirmed by these dissections, in which the following are seen:

(i) There are two arteries almost as often as there is one only (21/50). In one case (specimen 23) there were three.

(ii) The distal artery lies in the free border of the meso-appendix and supplies more than half the organ by length (in every case but one, specimen 33, where there were three vessels). It is called here the appendical artery. Any others are accessory appendical arteries (Table 2B).

(iii) The appendical artery is most often the *first* branch of the ileocolic (20/50) or the second (16/50). In only 9 cases did it arise from other final branches. Two came from the common caecal, two from the superior mesenteric, and the origin of one (specimen 25) is unknown (Fig. XV and Table 2A).

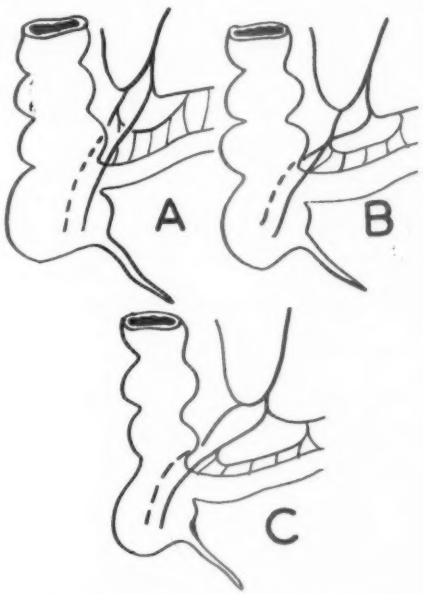

FIG. XII. Accessory arterial supply of terminal ileum. In 30 specimens other final branches of the ileocolic anastomosed with the ileal and so took part in supplying the terminal ileum. A shows this anastomotic arcade arising from the posterior caecal (14 cases). In B it arises from the common caecal (6 cases) and in C from the anterior caecal (9 cases).

TABLE 2

ORIGIN OF THE APPENDICAL ARTERIES

	Artery of Origin	*Specimen Number*	*Totals*
A. Of the distal ("appendical") artery	Ileocolic	1, 3, 4, 5, 6, 9, 10, 11, 12, 14, 22, 23, 30, 31, 32, 34, 35, 40, 41, 43, 44, 45, 47, 50	24
	Ileocaecal	2, 7, 15, 18, 20, 24, 38, 39, 46, 48, 49	11
	Caecocolic	8	1
	Common caecal	13, 37	2
	Posterior caecal	16, 17, 21, 33, 42	5
	Anterior caecal	19	1
	Ileal	26, 29, 36	3
	Superior mesenteric	27, 28	2
	Unknown	25	1
		Total:	50
B. Of accessory appendical arteries	Caecocolic	20, 23, 38	3
	Common caecal	13, 23	2
	Posterior caecal	5, 6, 9, 11, 12, 21, 22, 24, 25, 28, 30, 31, 32, 33, 39, 42 (two arteries), 45	18
	Ileal	27	1
		Total:	24

(iv) The appendical artery runs behind the terminal ileum (in one case only, specimen 41, it ran in front), and behind all other vessels in the terminal mesentery, before issuing in the appendical mesentery (Fig. XIVD).

(v) The appendical artery is usually the longest and most slender of all branches of the ileocolic. In this series its length varied from 6.5-14.5 cms. Average length of these 50 appendices was 7.5 cms., average length of the main artery 9.8 cms. In only 10 cases was the artery shorter than the organ, and then never by more than 2.5 cms. (1 inch). Roughly speaking, the length of the appendix is a guide to the length of the artery, both forming equal sides of an isosceles triangle with the attachment of the appendical mesentery as a base (this is not always so with retrocaecal appendices).

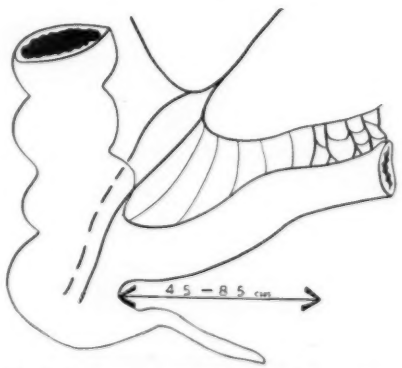

FIG. XIII. Arterial arcades in the terminal mesentery. As the diagram shows, arcade formation in these specimens only began at a distance of 4.5-8.5 cms. from the ileocaecal junction.

Being so long the artery, if divided, is able to retract far up into the terminal mesentery. Only its junction with fixed vesels limits an

artery's retraction, and in this case that junction may be 10.0 cms. away and out of easy reach. If the appendical mesentery at appendicectomy is dealt with in one step, slipping of the single ligature or clamp means dangerous retraction of the artery. Unless this mesentery is thin, narrow and transparent, it seems wise to deal with it in stages (Fig. XVI). Then, if a clamp falls off, intact branches or remaining clamps prevent retraction.

(Fig. XIX). A ligature including two or more arteries is obviously more likely to slip if they are pulling in different directions. Unless it is clear, and it rarely is, that there is only one appendical artery, it seems unwise to use a single ligature for the mesoappendix.

(viii) There are 3-12 main terminal branches of the appendical arteries. The average is about seven, as Koster and Weintrob (1928) say. These authors state that the branches run parallel straight into the organ without further division, but this is oversimplification. In fact the appendical artery often bifurcates (17/50), each of these primary branches dividing near the appendix (Fig. XXA). Single straight branches were found only in 8/50 cases (Fig. XXB). Sometimes the first branch alone divides (Fig. XXC), sometimes most or all do (Fig. XXD). Where there is a major accessory appendical artery, bifurcation of the main vessel (3/16) is less common. Patterns found where there were two vessels are shown in Fig. XXE, F, G. Marginal artery formation was found only three times (Fig. XXG).

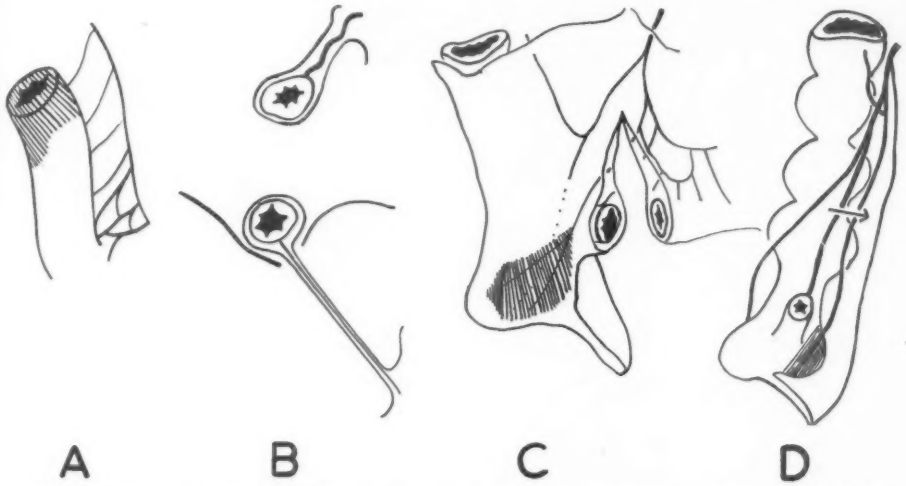

FIG. XIV. Surgical dangers of dividing the ileum in its last few centimetres. A shows necrosis of the ileal end due to poor blood supply. B shows the short terminal mesentery stretched taut when the ileal end is used for ileostomy. In C the anterior caecal artery is shown severed by division of the terminal mesentery, so endangering the blood supply of the anterior caecal wall. Other vessels — e.g. the posterior caecal as in D — may also be divided at this site with the same dangers.

(vi) In 5 specimens the only accessory appendical artery was a single small basal branch from the posterior caecal. Notice that a single ligature placed in the usual fashion (Fig. XVII) will always miss this vessel, which is only visible from behind.

(vii) In 16 cases there was a major accessory appendical artery, most often from the posterior caecal (12/16). (The total number of appendical and accessory appendical arteries in this series was 74 of which 18 (25 per cent.) were from the posterior caecal). This accessory vessel comes from a direction different to that of the main artery (Fig. XVIII). Nor is it possible to tell at operation whether there are two arteries or one, since the appendical artery itself bifurcates or gives its first branch high up, usually behind the ileum, in 50 per cent. of cases

(ix) The appendices varied from 3.8-11.4 cms. in length, the average being 7.5 cms. (Berry, 1896, 8.3 cms.; Collins, 1932, 8.2

cms.). There is no precise correlation between length of organ and number of main terminal arterial branches, though there may be a correlation of number with volume (not investigated). However, roughly speaking, there is one main terminal branch per centimetre of appendix. In no case did the appendical artery fall more than 1.0 cm. short of the tip (Fig. XXIA); in 37/50 it reached the very end of the organ. In 27/50 a branch of appendical or accessory appendical reached the very base of the appendix; in only 3 specimens was more than 2.0 cms. of base without an artery (Fig. XXIB). All this means is that the base and tip are as well supplied with blood as the rest of the organ. On the other hand the meso-appendix usually ceases some distance from the tip, so that the terminal artery and vein lie on the wall of the organ for an appreciable distance, and will be readily compressed if the organ distends and thrombosed if it is inflamed. This may account for the common occurrence of gangrene and even perforation at the tip of an organ elsewhere not grossly inflamed or swollen (Fig. XXII).

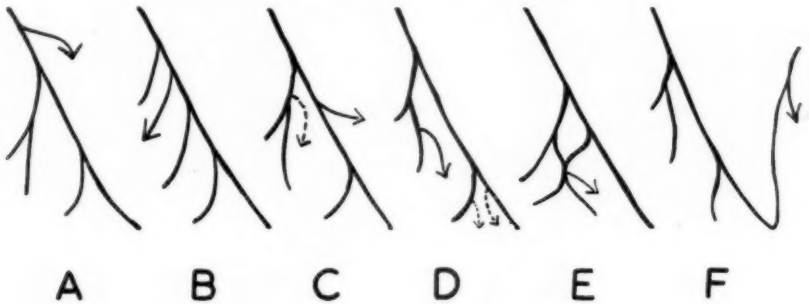

FIG. XV. Origin of the appendical artery. Most commonly (20/49) it is the first branch of the ileocolic (see arrow in A). Less commonly (16/49) it is the second branch or its equivalent (B and C). In D it arises from final branches of the ileocolic (9/49); in E from the common caecal (2/49); and in F from the superior mesenteric (2/49).

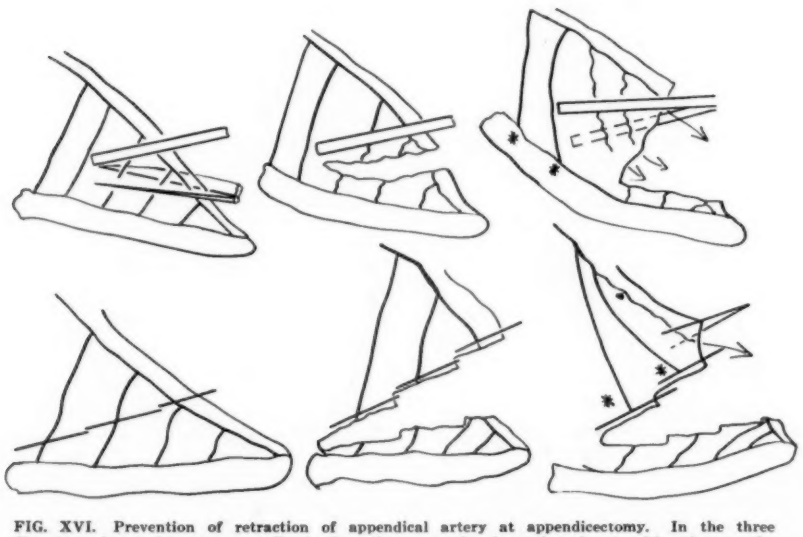

FIG. XVI. Prevention of retraction of appendical artery at appendicectomy. In the three diagrams above, the meso-appendix is first shown partly clamped and cut with scissors; the clamp falls off; but retraction of the divided vessels is limited by remaining intact branches (asterisks). In the lower diagrams the meso-appendix is divided over three clamps, one of which falls off, but retraction is prevented by the other two (asterisks).

(x) An appendical or major accessory appendical artery sent branches to the adjacent caecum in 14/50 of these specimens (Fig. XXIII). To preserve these branches, which are macroscopically end arteries (see above), the meso-appendix must not be pierced too far from the organ at appendicectomy if a single ligature is used (Fig. XXIIIB); or, alternatively, multiple clamps must aim for the base (Fig. XXIIID). Failure to observe these precautions may sometimes explain the rare accident of postoperative caecal fistula.

FIG. XVII. Basal accessory appendical artery. An arrow indicates this accessory vessel, which is a branch of the posterior caecal, and so almost invisible from in front.

3. *The appendical mesentery (or meso-appendix)*

The peritoneum of the appendix was carefully studied in the last 18 specimens (33-50 inclusive). In all cases it was smooth and transparent: there was no macroscopic evidence of previous inflammation, so that folds and reflections seen were fairly taken to be natural. Since these specimens were examined only after removal from the body, no statistical statement can be made about the position in life of each organ. Yet where the mesentery is short, the appendix clearly cannot move far and its position will not be altered by this *en bloc* removal. A long mesentery, on the other hand, allows any position to be assumed, and any found will be accidental.

(i) In no case was the appendix retroperitoneal but always had a mesentery, however short (cf. Treves, 1885). On the other hand definitely extraperitoneal appendices are occasionally found at operation (Fig. XXIV), though less commonly, I believe, than Collins (1932) would have it. Of Berry's (1896) 100 specimens, 6 were extraperitoneal. Of course a low lateral caecal fold will sometimes cover a retrocaecal appendix (Fig. XXV) and make it apparently extraperitoneal. In addition, inflammatory subperitoneal oedema and gross swelling of the appendix may combine to obliterate an already short meso-appendix, so that the organ may appear truly extraperitoneal at operation (Fig. XXVI).

FIG. XVIII. Different directions of appendical and accessory appendical arteries. Arrows show how the appendical (from ileocolic) and accessory appendical (from posterior caecal) must approach the appendix from different directions.

FIG. XIX. High division of appendical artery. In 22/50 cases the appendical artery divided (or gave its first branch) high in the meso-appendix, behind the ileum or mesentery.

(ii) In these specimens the longest part of the meso-appendix was always its free edge. If a short free edge is felt at operation, expect a short appendical mesentery. If at the same time the tip of the organ is distant from the

McBurney incision, the incision must be enlarged, unless the whole caecum is mobile and can be delivered (Fig. XXVII). If the meso-appendix is short, the tip distant, and the caecum immobile, abandon forcible delivery in favour of exposure (these injunctions do not necessarily apply with a paramedian incision).

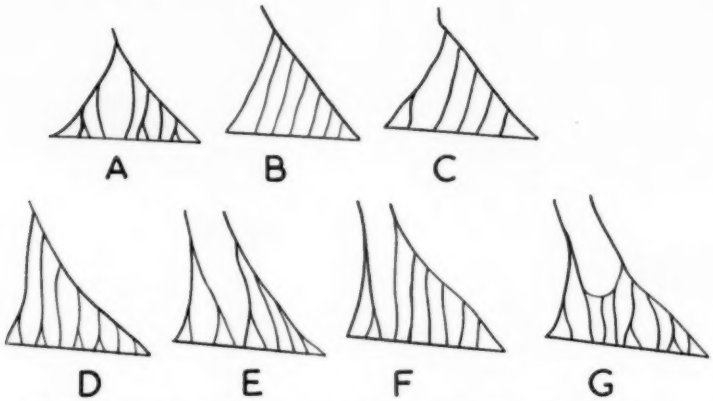

FIG. XX. Patterns of division of the appendical artery. Pattern A was found in 14 specimens, B in 8, C in 4, D in 8, E in 10, F in 3, and G in 3. In other words there were two arteries in 16 specimens and one which bifurcated in 14.

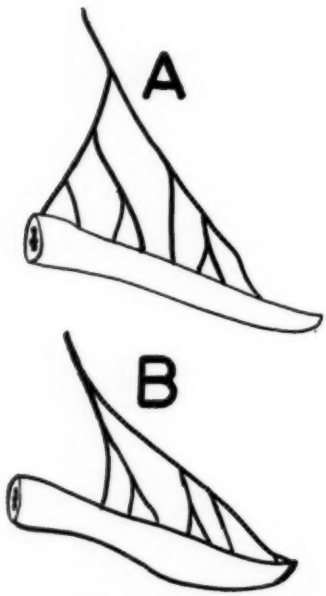

FIG. XXI. Arterial supply of base and tip of appendix. In 37/50 specimens the appendical artery reached the very tip of the appendix. In 13/50 it fell short of the tip (A) but never by more than 1.0 cm. A branch of the appendical or accessory appendical artery reached the very base of the appendix in 27/50 dissections; in the remainder a small basal segment, never more than 2.0 cms. in length, was without an artery (B).

(iii) In 8 of these cases the mesentery was very short, fixing the appendix in a retrocaecal or retromesenteric position. These appendices could not have assumed any position other than that found here (see above). An inflamed appendix in one of these positions probably owes its situation to its original peritoneal attachments (cf. Wakeley and Gladstone, 1928), not to inflammatory adhesions. As a corollary, one must always expect these high inflamed appendices to have short mesenteries and so to require exposure rather than delivery if the caecum is immobile (see above).

At the same time only 10/18 of these appendices could possibly have become pelvic in position; the meso-appendices of the others are not long enough. Do all inflamed high retrocaecal or retro-ileal appendices have short mesenteries? It seems likely, since the heavy swollen inflamed organ will sink below the caecum if it can; besides there is less room for it behind the caecum and terminal ilcum (Fig. XXVIII). It is its short mesentery, not inflammatory adhesions which accounts for the notorious *immobility* of the high posterior inflamed appendix. Many subcaecal inflamed appendices are caught by omentum and do not drop deep into the true pelvis.

(iv) The appendical mesentery usually falls short of the tip (cf. Quain, 1914) and always tapers towards it. In other words the tip, if free, is always the most mobile part; mobile not merely on the meso-appendix base but also on the appendix itself. Thus the tip, though furthest from the incision at appendicectomy, can be moved furthest; it is the part of the organ most easily delivered.

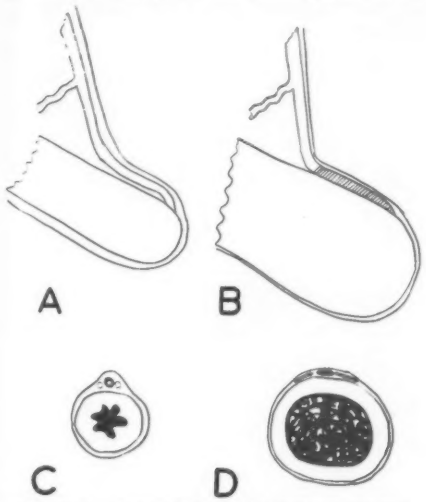

FIG. XXII. Vulnerability of the vessels supplying the tip of the appendix. The meso-appendix usually falls short of the appendical tip, so that the vessels to the tip lie against the organ (A). B indicates thrombosis of the artery by infection of the adjacent appendix. The lower diagrams show, in transverse section, first the normal tip (C), then compression of the vessels (particularly the venae comitantes) by swelling of the inflamed appendix (D).

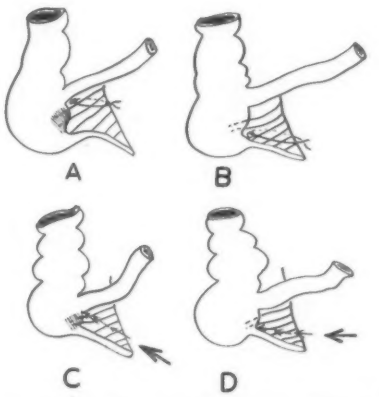

FIG. XXIII. Caecal branches of appendical arteries. A shows how a high meso-appendical ligature may interrupt branches of the appendical artery supplying the caecum. B shows the ligature avoiding these vessels. In C meso-appendical clamps applied parallel to the appendix are shown interrupting caecal branches of the appendical artery. D shows how clamps must be directed towards the base to avoid these vessels.

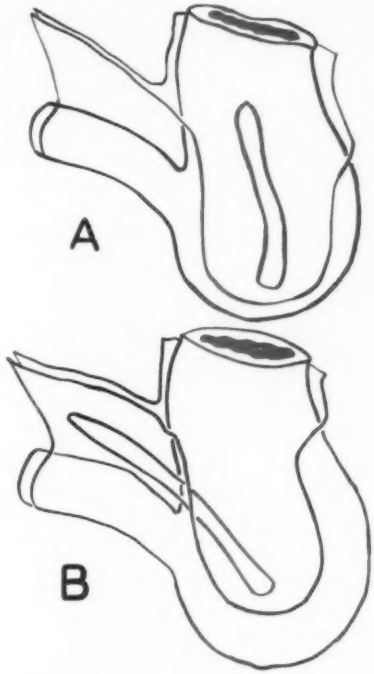

FIG. XXIV. Truly extraperitoneal appendices. Both diagrams are posterior views. A shows a retrocaecal retroperitoneal appendix, the peritoneal reflection from the caecum to iliac fossa taking off below the appendical base. In B the situation is essentially the same but the direction of the appendix is medial, so that half of it lies between the folds of the terminal mesentery.

(v) Only high posterior appendices are ever retroperitoneal. If the end of an anterior or low appendix is fixed end-on it is not by meso-appendix or appendical vessels, but by adhesions, which can be divided without damaging appendical vessels. (There is no need for this knowledge if one uses a paramedian incision, where the parts can be clearly seen, but only if one uses a McBurney incision, where dissection of adhesions is usually blind and blunt).

It follows that at appendicectomy via a muscle-splitting incision, one should find the base first, then the tip; the tip should be carefully freed by blunt dissection close to the organ; then it should be gently delivered

into the wound (alternatively the whole caecum may be delivered). The base is the most easily *exposed*, but the tip is the most readily *delivered*.

The arteries of the appendix in this series always entered its surface on one aspect and via one fold alone — the meso-appendix — no matter how many other folds were found in the vicinity (Fig. XXIX). The inferior ileocaecal fold (of Treves) is often present, often runs on to the appendix (Fig. 1171, Gray's *Anatomy*, 1947) and may obscure it and its mesentery completely (Fig. XXX). In these specimens it was always bloodless. After all, in no case did any accessory appendical vessels run to the appendix from arteries lying on the front of caecum or ileum. (In specimen 41 the appendical proper ran in front of the ileum; in specimen 19 it arose from the anterior caecal, but just after that vessel's origin from the ileocolic, high above and behind the ileum).

Another common fold which may give rise to confusion is a peritoneal reflection from the appendix to the peritoneum of the right iliac fossa (Fig. XXIX). This never carries vessels of any importance and is apparently homologous with the frequent lateral caecal fold from caecum to right iliac fossa (Fig. XXV) which forms the lateral wall of a subcaecal fossa (Gray's *Anatomy*, 1947). (This fold may be that which Clado (1892) describes as the "appendiculo-ovarian" in the female).

The meso-appendix proper is the thickest of all these folds and contains the most fat. Once it is found and identified by its thickness, shape and direction one may, at appendicectomy, safely divide other folds obscuring the organ (Fig. XXX) or attached to it.

CONCLUSIONS

1. The ileocolic artery usually bifurcates. The colic comes off one stem, the ileal from the other. The caecals may arise one from each stem, both from one, or both from a common caecal plexus. These are unlike the patterns traditionally described, all of which are uncommon.
2. The proximal ascending colon is supplied by caecal branches of ileocolic.
3. The blood supply of the terminal ileum is meagre and the ileal arteries most often communicate with, and are always close to, the caecals, making division of the last few centimetres of ileum hazardous to the ileum in all cases and to the caecum when that part of the bowel remains, even apart from the danger of the short terminal mesentery.

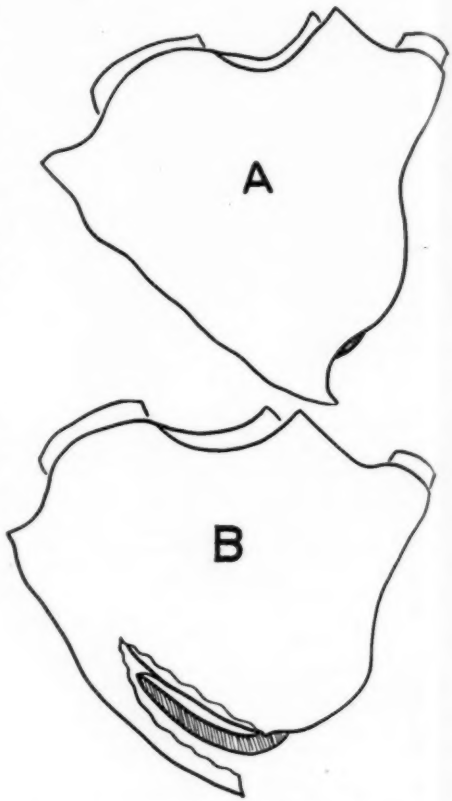

FIG. XXV. Apparently extraperitoneal appendix — due to lateral caecal fold. In A most of this retrocaecal appendix appears extraperitoneal, until division of the lateral caecal fold exposes it (B).

4. Multiple clamps or ligatures, aimed at the base, should be used in dealing with the meso-appendix at appendicectomy, because:
   (i) If a single ligature slips off, high retraction is possible, the appendical artery (contrary to previous descriptions) being the longest in the vicinity, and usually the first or second branch of the ileocolic.

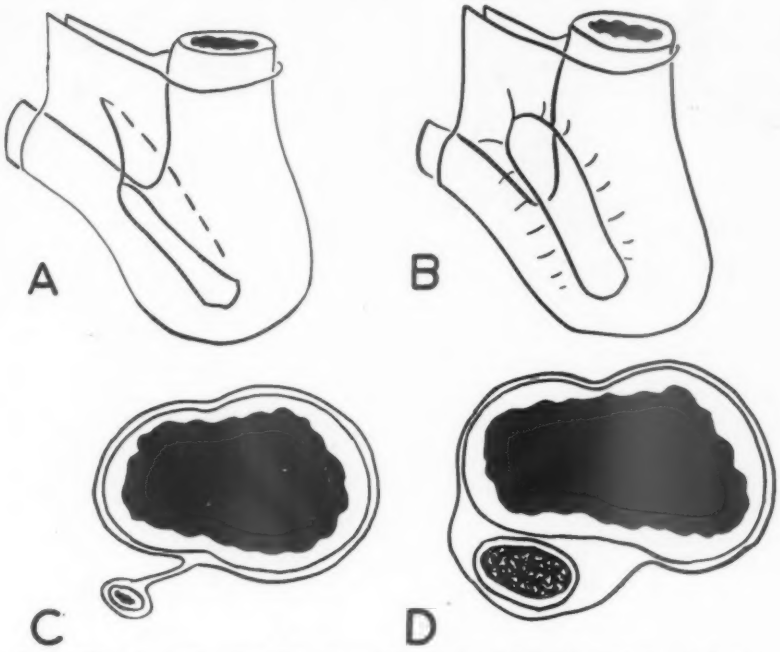

FIG. XXVI. Apparently extraperitoneal appendix — due to inflammatory oedema. A shows a retrocaecal appendix from behind, with a short mesentery. In B the same appendix is inflamed and swollen and this, combined with subperitoneal oedema, has obliterated the meso-appendix. C and D show the same developments in horizontal section.

(ii) In 50 per cent. of cases there are two arteries coming from different directions, which will tend to loosen and pull out of a single ligature.

(iii) In many cases an appendical artery supplies the adjacent caecum and a single ligature, high enough in the meso-appendix to allow a good cuff distal to it, may interrupt these vessels, which are macroscopically end arteries.

5. The vulnerability of the tip of the appendix to gangrene may be explained by the fact that the meso-appendix ceases short of it and the vessels to the tip lie against the wall of the organ.

6. The position of the inflamed appendix probably depends upon the original length if its mesentery, which is often short, and then holds the organ in a high posterior position. If the organ is found in this position, one must expect a short meso-appendix; the free edge, the longest part of the meso-appendix, is a good guide to

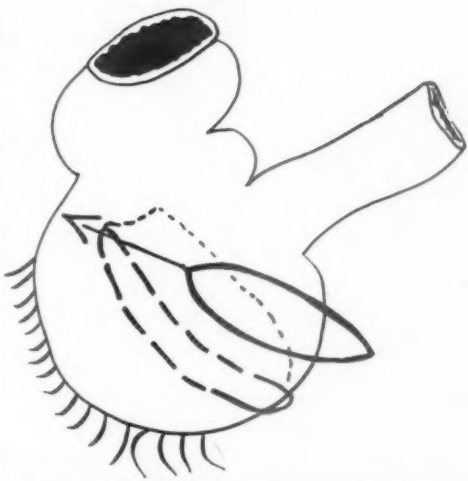

FIG. XXVII. Distant appendix tip, short meso-appendix and immobile caecum require extension of a McBurney incision. In the diagram the caecum cannot be delivered, because of a short lateral caecal fold, and the appendix cannot be delivered because its mesentery is short. Therefore the appendix must be exposed by extending the incision as shown by the arrow. (Of course the lateral caecal fold itself may be divided, if accessible.)

its length. If the meso-appendix is short, the tip distant, and the caecum immobile, the tip cannot be delivered via a McBurney incision but must be exposed, usually by enlarging the incision.

7. In all other circumstances one should try next to deliver the tip after exposing the base at appendicectomy. The tip will move furthest even though it is furthest away from the incision. Alternatively again one may deliver the caecum if mobile; this carries the appendix out with it.

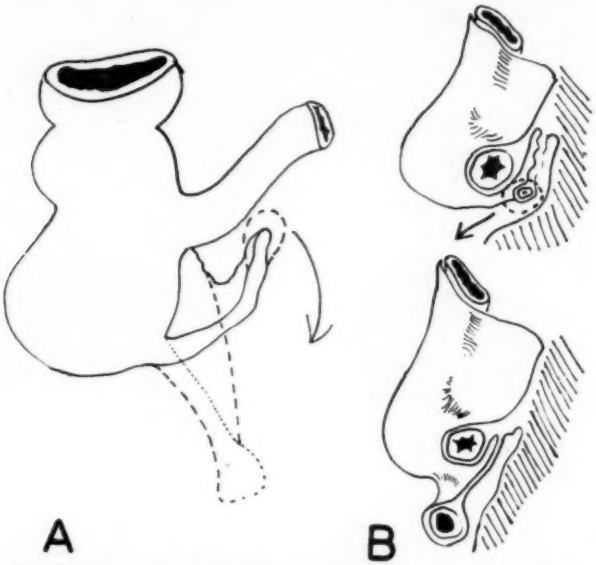

FIG. XXVIII. How an inflamed appendix may be supposed to drop below the caecum if the meso-appendix is long enough. A is an anterior view showing how its added weight bears downwards an inflamed appendix. In B (a medial view) the enlarging inflamed appendix pushes out of the retrocaecal fossa into the roomier peritoneal cavity.

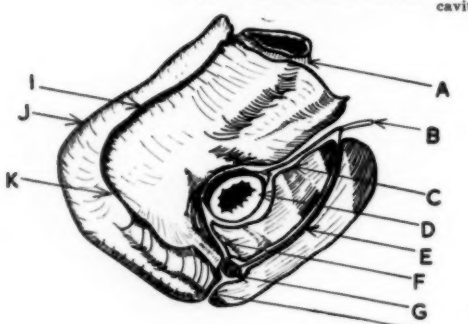

FIG. XXIX. Some folds found in relation to the appendix. In this diagram the ileum and appendix and related folds have been cut sagitally.
A. Ascending colon.
B. Ileocolic artery showing its ileal and appendical branches.
C. Terminal ileal mesentery.
D. Terminal ileum.
E. Meso-appendix.
F. Inferior ileocaecal fold.
G. Appendix.
H. Fold from appendix to right iliac fossa.
I. Caecum.
J. Cut edge of parietal peritoneum.
K. Paracaecal recess.

8. The tip of a low appendix is never buried except by adhesions, i.e. the organ is never completely retroperitoneal unless it is high in position behind caecum or ileum. These end-on adhesions can be safely freed without damaging appendical vessels.

9. High posterior appendices are sometimes truly extraperitoneal but a long lateral caecal fold, or inflammatory swelling may make a posterior appendix appear to be extraperitoneal when it is not.

10. The appendical vessels always travel in one fold only, the appendical mesentery or meso-appendix, easily recognized by its thickness, its free border tapering towards the tip, and its plane directed towards the back of the terminal ileal mesentery.

Other folds, particularly the inferior ileocaecal and an appendical homologue of the lateral caecal, can be safely divided after separation from the true mesoappendix.

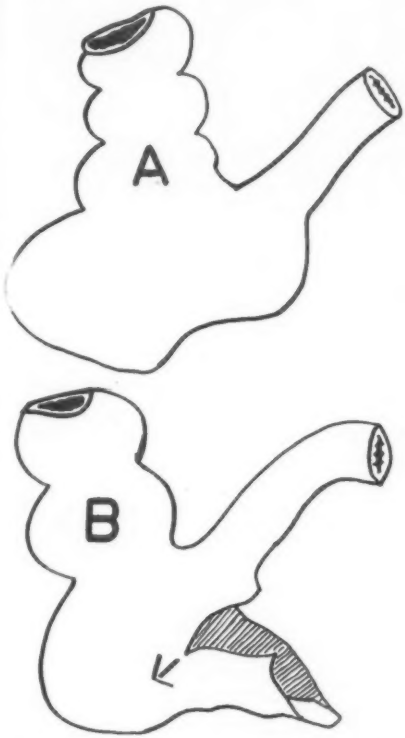

FIG. XXX. Appendix hidden by large inferior ileocaecal fold. In A the appendix and mesoappendix are completely hidden by an inferior ileocaecal fold prolonged on to the appendix. Division of this fold (B) exposes the appendix and its mesentery (shaded).

ACKNOWLEDGEMENTS

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THE PLACE OF SURGERY IN THE TREATMENT OF PULMONARY EMPHYSEMA

By JOHN HAYWARD

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THE scope of this paper does not include compensatory emphysema which is a physiological adjustment, interstitial emphysema which is a separate entity, or obstructive emphysema due to partial obstruction of a bronchus by an obvious lesion such as a tumour, foreign body, enlarged lymph gland, or, in certain cases of lobar emphysema in babies and infants, by softness of the wall of the lobar bronchus probably due to developmental absence of cartilage. The subject under discussion here is the common clinical type of emphysema, localized or generalized, due not to bronchial obstruction but to bronchiolar obstruction caused by bronchiolar obliteration following attacks of bronchiolitis (McLean, 1956a and b, 1957a, b and c). The discussion is based on 66 patients with this disease who came to surgery. As 7 required operations on both sides the total number of operations was 73.

Of these patients 47 were personal cases. I am indebted to my colleague, Mr. Ian McConchie, for the remaining 19. They are consecutive cases, being all the patients operated on for emphysema or its complications by our team over the past ten years. Patients operated on for other conditions such as tuberculosis or carcinoma who also suffered, sometimes severely, from emphysema are not included. Emphysematous patients treated by methods short of thoracotomy are also excluded.

THE SURGICAL PATHOLOGY OF EMPHYSEMA

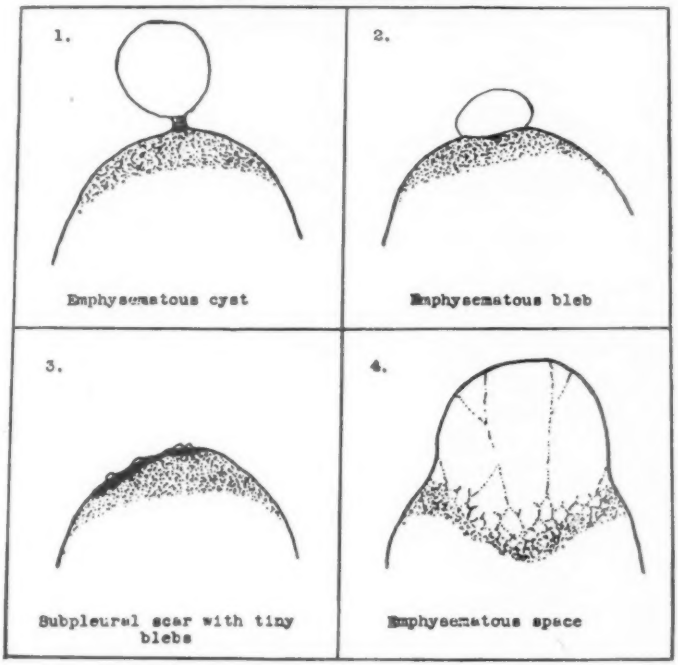
When bronchiolitis leads to bronchiolar obliteration without destruction of the peripheral alveoli these usually remain aerated by collateral respiration from neighbouring alveoli still supplied by patent bronchioles. The air seeps in through alveolar pores and cannot readily escape. Its to and fro movement with respiration is very small and it is said to be "trapped." It tends to collect under tension. The more broncioles obliterated in an area the longer and more tortuous are the collateral pathways and the greater the tension. It is this air trapping under tension which leads to the various changes such as alveolar breakdown and formation of bullae characteristic of emphysema.

The feature of the pathology of emphysema which is of greatest surgical importance is that it is only air trapping at or near the surface of a lobe which will produce large bullae. Bullae deeper in the lobe are never more than a centimetre or two in diameter and are usually much smaller.

Another important fact is that an enormous bulla may be blown up from what was originally a very small volume of lung tissue, perhaps only a few lobules. Such bullae compress the remaining lung and reduce its ventilation. As they grow, the lung markings seen in the radiograph disappear over a larger and larger area of the lung field. This has been called "vanishing lung." It is important to remember that the original volume of lung tissue which gave rise to the bullae was small and superficial and that the remaining deeper part of the lung, though more or less invisible on the X-ray film, has not really vanished. After relief of the compression by successful removal of the bullae it will reappear and function again. It is true that its function may still be impaired if, as is often the case, it is emphysematous too, but this function, though reduced, may nevertheless be of great help to the patient. Indeed, in a patient with extensive bilateral bullous emphysema with considerable compression of both lungs one can be quite sure, however bad the radiological appearances, that a very large amount of useful lung tissue remains, because to maintain ventilation sufficient for survival of the patient while it is compressed the lung tissue must retain a great deal of its function.

The term bulla may be applied to any blown up space in emphysematous lung. From the surgical point of view it is only the superficial bullae which are important and it is helpful to distinguish different types. Superficial air trapping subjects the visceral pleura to increased tension to which it responds by growth in area and, to a lesser extent, thickness. This hypertrophic growth of visceral pleura and subpleural connective tissue which is nourished by an increased bronchial arterial supply may occur even when the underlying lung tissue is undergoing extensive disruption and atrophy. Different types of bullae are produced depending on whether the air is trapped immediately beneath the visceral pleura or a little more deeply but still near enough to the surface to affect the pleura.

DIAGRAMS
of types of emphysematous bullae



Air trapping immediately beneath the pleura may blow up cysts which become pedunculated and occasionally reach enormous size (Diagram 1), or blebs which are sessile and usually only up to a centimetre or two in diameter (Diagram 2). The cysts have a complete wall of their own and are therefore properly so called. The wall consists of new growth of fibrous tissue and overlying pleura so that cysts and blebs are not so much changed lung as additional excrescences on the surface of the lung. Apart from the tiny subpleural area of lung originally scarred so that air trapping occurred the lung may be quite normal, though cysts and blebs may also grow on the surface of lungs which are extensively affected by emphysema.

The larger an emphysematous cyst grows the thicker its wall becomes. Since a constant pressure of air inside it exerts a tension in the wall which increases with the diameter the stimulus which produces the thickening with increasing size is apparent. If the thickening does not keep pace with the increasing tension in the wall the cyst comes to an end by rupturing. The internal surface of small cysts is smooth. Large ones

with thick walls are irregularly ridged on the inner surface. The area of the cyst which communicates with the lung is small and scarred, though the scar may not be large enough to be detected by palpation. The air conducting channels through the scar are seldom visible to the naked eye.

Emphysematous cysts are frequently multiple and often bilateral. They are commonest at the apices and along the sharp edges of the lobes. Several may grow together in a cluster.

Areas of subpleural scarring from old, clinically unrecognized, non-specific inflammation are common in adults, especially at the apices of the lungs. The scars form immediately beneath the pleura, are about 2 or 3 millimetres thick and extend over an irregularly shaped area which looks greyish and is easily palpable, being somewhat leathery to the touch. Such areas are a frequent incidental finding in thoracotomies for other diseases. Occasionally very small air passages survive in the scar and pass through it to the subpleural layer. Then multiple blebs a few millimetres in diameter form between the scar and the overlying pleura (Diagram 3). Though they usually remain very small, these blebs may rupture and cause spontaneous pneumothoraces. When a bleb has ruptured its outer wall disappears and a small pit is seen in the surface of the scar rather like a pore in the skin. Emphysematous cysts sometimes form at the margins of these scars.

When air trapping occurs in a larger area and depth of lung tissue but still sufficiently near the surface to distend the pleura a space is formed which is usually more within the lung than outside it. The pleura, subjected to increased tension, grows as usual, so that the affected part bulges the surface of the lobe, but the space extends down into the lung (Diagram 4). In the lung the space has no wall and is bounded only by emphysematous lung tissue with residual strands traversing the space to the pleural surface. To distinguish these lesions from cysts which have a complete wall I call them emphysematous spaces. Thus emphysematous bullae may take the form of cysts, blebs or spaces.

Intermediate forms occur in which the space has a base narrower than its maximum diameter and sometimes even small enough to resemble a pedicle, but when the space is opened emphysematous lung tissue is seen in its base.

Emphysematous spaces may be widespread and bilateral or localized to one lobe or even one segment. Cysts or blebs or both may occur as well in other parts of the same lobe or lung. The bulging spaces greatly enlarge the affected parts of the lung, so that this type of emphysema is often called hypertrophic emphysema.

FIG. 1. Lateral film of a large infected emphysematous space lying in the oblique fissure of the left lung in an elderly man. As the infection subsided the space was obliterated.

COMPLICATIONS OF EMPHYSEMA OF SURGICAL IMPORTANCE

Infection is rare in emphysematous spaces and very rare in emphysematous cysts. When it occurs it is usually low grade and may result in obliteration of the space or cyst (Fig. 1). Even tuberculous infection may very rarely spread to an emphysematous space which then becomes a tension tuberculous cavity and must be treated as such. Pleural adhesions in the form of strings and sheets are fairly common over and beside cysts and spaces. Possibly some are the result of past mild infections in these lesions,

but perhaps others formed during the original infections which produced the bronchiolar obliteration which led to the emphysema. In that case the adhesions were there before the cysts and spaces developed. Complete obliteration of wide areas of the pleural space by direct adherence is very rare, presumably because cysts and large spaces need free pleural space in which to develop.

and medical investigation, though occasionally prompt relief of tension by a needle or intercostal tube is required.

If a thin-walled cyst or bleb ruptures, its wall collapses and the traumatic inflammation is usually sufficient to seal the very small communications with the lung. With the air leak sealed the pneumothorax is absorbed,

TABLE 1

Type of Case	*No. of Patients*	*No. of Operations*	*Sex*	*Average Age*
Chronic or recurrent pneumothorax; generalized emphysema absent or, at most, mild	36	41 (5 bilateral)	31 M 5 F	31 M 19-52 av. 30 F 25-60 av. 38
Chronic or recurrent pneumothorax complicating moderate to severe generalized emphysema	13	14 (1 bilateral)	13 M	52 All M 40-63
No pneumothorax Severe emphysema	15	16 (1 bilateral)	14 M 1 F	52 M 45-63 F 45
No pneumothorax Huge single air cyst	2	2	1 M 1 F	M 58 F 53
Total	66	73	59 M 7 F	

Rupture of cysts and blebs is fairly common and of spaces much less common. The result is, of course, a spontaneous pneumothorax. Since cysts may have very vascular walls and adhesions over or near them may also be vascular and may be torn when the lung collapses, a little blood may escape and cause a small pleural effusion in the spontaneous pneumothorax. Rarely a large haemorrhage occurs. One such case of spontaneous haemopneumothorax is included in our series. About 3 pints of blood-stained fluid and clot were removed from his pleura at the operation during which a cluster of cysts on his lower lobe were also excised.

Pneumothoraces complicating emphysema seldom develop a high tension so they are rarely lethal except when simultaneously bilateral or when they occur in a patient previously in respiratory distress because of widespread severe emphysema. Usually there is plenty of time for admission to hospital

usually within a month. When the lung comes up some new pleural adhesions may form.

The air leak may fail to seal, or may seal and re-open thus leaking from time to time. Also, as cysts and blebs are usually multiple, others may rupture causing further leaks. If further leaks occur within a month the pneumothorax will fail to absorb within that time and should then be regarded as chronic. If the time between leaks is greater than a month (it may be years) the pneumothorax absorbs and then recurs. There is no fundamental difference between chronic and recurrent spontaneous pneumothoraces. It is only the chance difference of interval between recurrent air leaks that determines which will occur.

With absorption after each recurrence the pleura becomes a little thicker and more adherent until the condition cures itself either because the pleura is so thick that it resists further rupture or because no pleural space

remains for air to leak into. The condition may also come to an end because there are no more emphysematous lesions to rupture.

When an emphysematous space ruptures it does not usually collapse and heal as so often occurs with cysts and blebs and spontaneous sealing of the air leak is less likely to occur. The pneumothorax is therefore more likely to be chronic. Chronic pneumothoraces result in the deposition of a fibrinous "skin" over the visceral pleura which ultimately becomes fibrous and prevents re-expansion of the lung even if the air leak is sealed. Despite the presence of a bronchopleural fistula these chronic pneumothoraces are very slow to become infected and turn into empyemata.

Some interesting points concerning the incidence of trouble requiring surgical aid emerge from the study of our cases (Table 1). The preponderance of males corresponds to the much higher incidence of emphysema in men, and in the women the troubles arise later in life. The relatively small number of cases collected in a decade in the practices of two full-time chest surgeons indicate that chronic or recurrent pneumothoraces complicating emphysema and requiring operation are not very numerous in this country. Though only 15 cases were operated on for severe emphysema (without pneumothorax) this number is not a fair indication of the incidence of gross emphysema suitable for surgery. Operations for emphysema without pneumothorax were only begun by us in 1951 and there must be many more cases which will be referred as the results improve and physicians become aware of what can be achieved.

Though obvious clinical emphysema is common among older men less than one-third of our cases of spontaneous pneumothorax come from this group who were all over 40. The ages of the men in the group without clinically evident emphysema ranged from 19 to 52, but only two of them were over 40 and it is possible that both should have been put in the emphysematous group. There will always be difficulty in classifying early cases because the changes of generalized emphysema progress for a long time before they become macroscopically evident. Our figures indicate that chronic or recurrent spontaneous pneumothoraces in men under 40 are likely to be due to very localized emphysema in otherwise apparently normal lungs, whereas in men over 40 they are usually a complication of clinically evident progressive generalized emphysema. It would be interesting to know definitely if the younger group are more likely to suffer from generalized emphysema as they grow older than other men who have not had pneumothoraces from localized emphysema in their early adult life. I suspect that they are.

In our 41 operations for chronic or recurrent pneumothorax without obvious generalized emphysema we found only subpleural scars, with or without visible tiny blebs, in 11; cysts, sometimes with additional scars as in the first group, in 27 and localized spaces in 3. Evidently localized emphysematous spaces seldom develop in otherwise normal-looking lungs. They are usually localized accentuations of generalized emphysematous change and this was what was found in all the 14 operations for pneumothorax in clinically emphysematous patients. Several had cysts and blebs as well as the spaces.

A curious finding was that in all 7 of our bilateral cases exactly the same type of lesion was found on both sides; e.g. if a subpleural scar with blebs was found at the apex on one side and no cysts, a similar scar without cysts was found on the other side; and so on. The number of bilateral operations is too small to assess the significance, if any, of this finding.

The two huge single air cysts (Table 1) had small pedicles and, despite the age of the patients, the rest of the lung in both cases appeared normal and expanded readily once the pressure of the cyst was removed. There was a third similar case in the series — one of the 36 patients with pneumothoraces but no generalized emphysema. This was a woman aged 60 with a chronic left pneumothorax and massive collapse of the left lung for over six months before she would agree to treatment. At operation a linear rent 4 inches long was found in an enormous collapsed cyst wall. The cyst had the usual narrow pedicle. The moment the pedicle was clamped the anaesthetist could easily inflate the lung which then appeared normal. It is strange that these giant emphysematous cysts always seem to occur singly.

THE SURGERY OF EMPHYSEMA

General considerations

Many operative procedures have been tried for emphysema. The advocates of pneumoperitoneum with or without an abdominal belt to raise the depressed diaphragm only claim slight improvement (Carter, 1950) and this treatment may be dismissed. On the assumption that it might halt or retard the progress of the disease and improve the pulmonary ventilation, denervation of the lung has been tried in various ways. Dorsal sympathectomy, vagotomy, peri-arterial sympathectomy, of the pulmonary artery, or all three (Abott *et alii*, 1953) have been claimed to result in benefit sometimes. I have never tried them because it is difficult to see how denervation can materially affect the severity or progress of a condition the basis of which is bronchiolar obliteration due to bronchiolitis.

In addition to complete denervation of the lung Crenshaw and Rowles (1952) advocate parietal pleurectomy and poudrage on the assumption that the vascular connections with the chest wall which will develop should help the patient by improving the blood supply to his emphysematous lung. This, too, seems illogical. There is not much point in attempting to bring more blood to lung tissue distended with trapped air. Increase of circulation without increase of ventilation is hardly likely to be beneficial. The benefit they claim was almost certainly due to the removal of cysts and spaces which they did at the same operation.

The thesis of this paper is that the only sound indication for operation in emphysema is the possibility of producing a significant increase in pulmonary ventilation by the permanent removal of trapped air which is, for practical purposes, a space-occupying lesion in the thorax. The air may be trapped in large emphysematous cysts or spaces, or in the pleural cavity (spontaneous pneumothorax). In either case there is compression of functioning lung and it is evidence of this compression which is the indication for consideration of surgery designed to remove the large collections of trapped air and to ensure, as far as possible, that they will not collect again.

The operations therefore fall into two groups. The first are designed to deal with spontaneous pneumothoraces by achieving their absorption and preventing recurrences. Here the patients frequently have no evidence of generalizd emphysema and suffered no dyspnoea before the onset of the pneumothoraces. Such patients should be restored to full normal activity. The second are designed to remove large emphysematous cysts and to remove or diminish in volume large emphysematous spaces which contribute significantly to the dyspnoea in patients with severe generalized emphysema. In such patients the respiratory disability should be greatly lessened.

All the operations in the series of cases presented in this paper fall into one or other of these two groups. It is considered that at present surgery has nothing to offer patients whose emphysema is generalized without sufficient local accentuation to produce large cysts or spaces and without the complication of chronic or recurrent spontaneous pneumothoraces.

The surgical management of chronic and recurrent spontaneous pneumothoraces

There are two possible ways of stopping recurrence of spontaneous pneumothoraces. One is to obliterate the pleural cavity. The lung cannot leak if there is no space for the air to leak into. The other is to deal directly with the areas on the surface of the lung which are potential sources of further leakage. This requires thoracotomy whereas the first method does not.

Obliteration of the pleural space by the creation of a mild chemical pleurisy with agents such as talc and silver nitrate has been used extensively with considerable success and, like others, e.g. Brock (1948), we began by using this method which then seemed preferable to a major operation. We found the treatment unpleasant and painful for the patient and the post-operative course sometimes troublesome. The pleural surfaces must be in contact during the period of acute inflammation if they are to adhere satisfactorily and it is not always easy to keep the pleural cavity free of air and effusion. Pockets of air or fluid may collect and the risk of empyema is not entirely absent. If it occurs it is liable to become chronic because the chemical agent causes pleural thickening.

It soon became apparent that when the cause of the pneumothoraces was large spaces or cysts these would be better removed and the practice of preliminary thoracoscopy grew up. If bullae were seen thoracotomy was advised. The post-operative course after thoracotomy was found to be smoother, less painful and easier to manage, and the period of convalescence no longer. Bilateral cases were less upset at the thought of a second thoracotomy than a second injection of silver nitrate and the results were quite as good. Also treatment directed at the cause seemed more logical. Thoracotomy is now advised in most cases.

At operation cysts and blebs are easily removed after clamping the pedicle or base and ligating or oversewing it. Small subpleural scars can be excised after clamping beneath them. Then the lung tissue in the clamp is oversewn. Alternatively they may be invaginated without removal by oversewing them. If the scars are large enough for either method to deform the lobe more than slightly it is better to rupture any tiny bullae on them by rubbing them with dry gauze and then to paint them with freshly dissolved 10 per cent. silver nitrate keeping the chemical away from normal pleura. The silver nitrate induces fibrosis which permanently occludes the tiny bronchopleural fistulae in the scar. It no doubt helps to produce post-operative pleural adhesions over the scar too, but this is not the prime reason for its use here. The precise application of the silver nitrate when and where it is required is one of the satisfactory features of treatment by thoracotomy. The methods of dealing with spaces will be described later. When combinations of these lesions are present each is treated as required. If there is a "skin" over the lung it is decorticated. The chest is then closed with closed drainage, suction being added when necessary.

The thoracotomy may not produce extensive permanent adhesions. In fact it is hoped that it will not, so that there will be minimal impairment of lung function. Adhesions are unnecessary when the sources of air leaks have been dealt with effectively.

Our series of operations includes 41 which were done on patients with chronic or recurrent pneumothoraces without evidence of generalized emphysema. They had no dyspnoea prior to the pneumothoraces and no clinical or radiological evidence of the generalized disease. At operation, apart from the local superficial lesions, the lung looked and felt normal or very nearly normal. There were no deaths and no late recurrences of pneumothoraces in this group. Only one early transient recurrence occurred in a patient who will be described below (Case 1). The treatment is therefore safe and effective and we now advise thoracotomy for all patients of this type.

In none of these 41 operations did we find on the lung surface no lesion meriting surgical attention. We therefore always feel justified in assuring the patient's physician that we shall find a localized lesion to treat. This is important because cysts, blebs and subpleural scars are usually not definitely visible in the pre-operative radiographs. There is no point in proving their presence by a pre-operative peep through a thoracoscope.

Serious complications resulted from 2 of the 41 operations and these two cases are worthy of description.

Case 1

A man, aged 24, in whom previous poliomyelitis had left residual pharyngeal weakness which made coughing and swallowing difficult and created problems in post-operative management, had had bilateral spontaneous pneumothoraces and was referred for surgery with a left-sided recurrence. At operation apical cysts were excisd and subpleural scarring painted with silver nitrate. His post-operative course was smooth except for a mild bronchopneumonia which responded to treatment. Within a fortnight of returning home his right pneumothorax recurred and failed to absorb so, eight weeks after the left thoracotomy, his right chest was opened with similar findings and treatment of the lung. In addition, unfortunately, I removed all the costal parietal pleura on this side thinking it would make post-operative adhesions more certain to develop. It was before I had become confident that dealing with lesions on the surface of the lung made extensive obliteration of the pleural cavity unnecessary. Within thirty-six hours he had a clotted haemothorax and severe bilateral bronchopneumonia requiring, because of his difficulty in coughing, repeated bronchoscopies. On the fourth day, during a bronchoscopy, he developed a left apical pneumothorax which, though small, made his already critical state desperate. It was effectively treated by suction through an intercostal catheter for three days and the pneumonia gradually subsided, but he developed a right empyema which had to be drained two weeks later and slowly healed. He has been well and at work for the past three years with no further chest trouble.

Case 2

A man, aged 33, with recurrent left pneumothoraces is the only other patient whose costal parietal pleura I removed. He also bled postoperatively and developed a clotted haemothorax. His chest was re-opened and the clot removed on the fourth day. There were no further complications.

The removal of the parietal pleura in these cases is unnecessary and may be dangerous.

Our next group of operations for pneumothoraces were on 13 patients who had moderate to severe generalized emphysema. They were all over 40 and presented the typical clinical picture of emphysema long before the onset of the pneumothoraces which were merely the final factor which led to them being referred to us. Operation in this type of case is quite a different proposition from surgery in the first group. It is dangerous and should only be done when the patient is a reasonable surgical risk as regards age and general condition and when his emphysema is of the sort which would have been suitable for surgical treatment even if no pneumothoraces had occurred.

Our 13 patients were of this type. From the surgical point of view their pneumothoraces were incidental and their operative treatment was the same as in the third group of 15 patients who were operated on for emphysema alone. These two groups totalling 28 patients will therefore be considered together below, but to stress the dangers of thoracotomy for pneumothoraces complicating severe emphysema it may be mentioned here that among our 13 patients there was 1 death, 1 acute empyema and 2 chronic empyemata which did not heal until a small thoracoplasty was done. All the 12 survivors now have less respiratory disability than before their pneumothoraces occurred because large emphysematous spaces have been removed. It was because they had the sort of spaces which were suitable for surgical treatment that operation was justifiable. In none of the 12 has there been a recurrence of pneumothorax.

In patients of this type who are unsuitable for surgery we usually treat the pneumothorax by suction on an intercostal catheter for about a week. Some adhesions will form, as least at the site where the tube entered the pleural cavity, and this treatment causes very little disturbance to the patient and can easily be repeated if the lung goes down again. Sometimes, after catheter suction is effectively coping with the leak and the lung is re-expanding, injection of silver nitrate into the pleural cavity is desirable.

The surgical treatment of large emphysematous spaces

Pulmonary ventilation in emphysematous patients with large lung spaces can be improved by reduction in size or removal of the spaces. In the section on surgical pathology it has been mentioned that such spaces may very rarely be obliterated by low grade infection which sometimes occurs in them. It would be ideal if a simple, safe method of creating chronic inflammation in emphysematous spaces which would lead to their obliteration could be discovered, but this discovery has not yet been made.

Drainage of the spaces, similar to Monaldi drainage of tuberculous cavities, has been tried (Weisel, 1955) with some success but the drainage usually has to be maintained for months. Complications are common and the treatment is not satisfactory unless most of the spaces on the side being drained happen to communicate so that the one tube sucks air from them all. Presumably the ultimate sealing of the bronchocavitary fistulae and obliteration of the spaces is due largely to the secondary infection which always complicates prolonged tube drainage of any cavity.

It seems better to open the chest and deal with the spaces directly. Sometimes they bulge out of the surface of the lung so much that when they are drawn up into the wound the base is narrowed sufficiently for clamps which compress a minimum of useful lung tissue to be put across it. Then the whole space can be excised and oversewn. I use 00 intestinal chromic catgut on an atraumatic needle. Unfortunately the base often covers too wide an area of the surface of the lobe for clamping. Sometimes the whole outside of a lobe may consist of one huge space with the useful tissue of the lobe compressed into a small central core at the hilum.

One method of dealing with such cases is simply to excise the outer visceral pleural wall of the space leaving the lung underneath naked and bubbling. Very few blood vessels have to be ligated when this is done and sometimes none at all. If more than capillary ooze occurs it is an indication that the excision is encroaching on functioning

lung tissue which ought to be left untouched. Some authors speak of ligating bronchocavitary fistulae. In my experience the whole naked surface leaks air and there are rarely individual fistulae big enough to be suitable for ligation. The chest is closed with suction drainage. In favourable cases the functioning lung previously compressed re-expands and the naked area comes out to the parietal pleura and adheres to it.

When the inner boundary of the space has adhered to the parietal pleura in this way the space has been as completely eradicated as if it had been excised. No useful lung tissue has been removed and the lung has been able to expand freely with none of the distortion which may be produced by sewing up the visceral pleura. In theory this method is ideal but in our cases the incidence of serious complications was so much higher than when the lung was covered with pleura that we now never leave any extensive area uncovered.

When an emphysematous space is too extensive to be clamped and excised it is usually better either to excise most of its outer wall and sew the edges together or to plicate the outer wall, in a series of places if necessary, until the lobe has been reduced to somewhat less than its normal volume. Both methods deform the lobe and neither completely removes the space. Originally I feared that it might blow up again, but this has not occurred so far in any of our cases. Perhaps the trauma to the spaces at operation, to which post-operative infection is sometimes added, is sufficient to obliterate what remains of them. Though the pleura is sewn carefully with atraumatic needles there is usually a brisk air leak from the suture holes and post-operative suction drainage is necessary.

In cases in which the large spaces are confined to one lobe or one segment and the rest of the lung shows only mild emphysematous changes, it may be considered wise to do a formal lobectomy or segmental resection. Theoretically at least, this is rarely advisable. All operations in these patients are designed to increase pulmonary ventilation as much as possible and it must be remembered that large bullae only represent the most superficial parts of the lobe. The deeper parts often retain considerable potential function which will be sacrificed if the whole lobe or segment is removed.

Massie and Welchons (1954), reporting 7 cases in some of whom they did segmental or lobar resections and in the remainder only local excision of bullae, noticed that the latter operation saved useful lung tissue. Stringer and Burnett (1956) made the same observation and therefore condemned resection of whole pulmonary units. They recommend obliteration of the bullae by removal of part of the pleural roof and suturing the remainder with stitches which include the surface of the underlying lung, but sutures which bite into the lung will damage and deform it if they are deep enough not to tear out and it has been shown above that inclusion of lung tissue in the stitches is unnecessary.

We have done 30 operations for extensive bullous emphysema on 28 patients (2 bilateral). These include the 13 patients in whom the final factor which caused them to be referred for surgery was a chronic or recurrent pneumothorax. All these patients were severely disabled by dyspnoea and most of the 15 without pneumothoraces were complete respiratory cripples who were quite desperate and pathetically anxious for operation regardless of the risk from the moment they first heard that surgery might give them some relief.

When the ten-year period over which these cases have been collected began it was not realized that emphysematous spaces could be tackled with any degree of safety. During the first four years we were beginning to do a few thoracotomies for pneumothoraces instead of injecting silver nitrate and our operations on emphysematous spaces began only 6 years ago. The patient who helped to convince me that these operations were necessary is worth describing.

Case 3

A man of 41 was so crippled with emphysema that he had been unable to work for a year when he was referred to me, seven years ago, with his second left spontaneous pneumothorax. Drainage with an intercostal catheter prevented his death but at the end of ten days the air leak was just as vigorous and he was still cyanosed and orthopnoeic. The radiograph was interpreted as showing 2 or 3 large lung cysts, so the chest was opened with the intention of excising them on the assumption that they had pedicles which could be clamped. It was found that they were not cysts but parts of bulging emphysematous spaces extending over the whole surface of the lung with no hope of clamping and excision. An attempt to sew the small visible air leak

only created an even bigger leak through the suture holes. At this stage his condition was desperate, so silver nitrate was sprayed over the lung and the chest rapidly drained and closed. The lung came up and the pneumothorax did not recur, but he remained a respiratory cripple and died of his emphysema eighteen months later. During the whole of this eighteen months he was a misery to himself and his people. It would have been better if he had died of his pneumothorax.

It was clear to his physician (Dr. Clive Fitts) and myself that a large part of the problem in his chest was mechanical and that, therefore, there ought to be some surgical method of relieving it. As he was obviously going to die very soon without operation there was nothing to be lost by a surgical attempt. It took a week to find an anaesthetist who would accept him. Ultimately Dr. A. Nathan accepted the responsibility. By some miracle the patient survived the delay. The right chest was

TABLE 2

OPERATIONS FOR LARGE EMPHYSEMATOUS SPACES ASSOCIATED WITH GENERALIZED EMPHYSEMA

Type of Operation	*No. of Operations*	*Incidence and Type of Severe Complications*
Excision of outer wall of space without suture	8	3 deaths — 1 respiratory failure 2 fulminating infection 2 chronic empyemata—1 required small thoracoplasty 1 acute empyema 1 burst wound
Excision and suture or plication or both	19	1 chronic empyema requiring thoracoplasty 1 acute empyema 2 severe bronchopneumonia
Segmental resection or lobectomy	2	No complications
Total	29	3 deaths — 8 severe complications

This case showed that it was not much use merely curing a pneumothorax in a patient with gross emphysema. It was obvious that, if possible, something should be done to the lung, and in the other 27 patients in this group the emphysematous spaces were dealt with in various ways. The first of these 27 had a big influence on our management of several subsequent cases and he will now be described.

Case 4

A man, aged 52, was first seen eight years ago with gross bilateral bullous emphysema. He had recently had to give up work altogether, having done less and less for the previous four years. Physiotherapy was tried with very little benefit. Chemotherapy controlled recurrent acute lung infections but he was still unable to work. Then, six years ago, over a period of a few months his dyspnoea became much worse, and I was called in again when he was bedridden, orthopnoeic, cyanosed and irrational. The radiographs showed that in the preceding few months the spaces on the right side had increased rapidly in size until the whole of the markings of the right lung had vanished and the mediastinum was displaced well to the left.

opened within five minutes of induction of the anaesthetic and the extremely tense right lung which immediately bulged out of the wound was stabbed with the knife. Air escaped with a violent hiss, the lung collapsed like a burst balloon and the patient's colour immediately became pink for the first time in many months.

I then found that it was the upper lobe which had been stabbed and I began to cut away the visceral pleura, intending to sew the edges together when I reached the margins of the space. But the space had no margins and when I had finished removing its outer wall the whole visceral pleura of the upper lobe had gone. The lobe was nothing but a small, naked, tattered, greyish-black remnant blowing bloody bubbles all over. The lower and middle lobes also contained emphysematous spaces. As the operation was experimental there seemed no point in stopping half-way, so the outer walls of these spaces were also removed with the result that the lower lobe was completely and the middle lobe one-third denuded of pleura. As can be imagined the right lung then looked a useless wreck, but nothing could be done except drain the pleura and close the chest. Contrary to the gloomy predictions of many anaesthetists, spontaneous respiration was resumed after the anaesthetic. He survived a stormy convalescence complicated by severe infection in the right lung followed by a right apical empyema

which took six months to close. To our astonishment, the right lung re-appeared in the radiographs with normal-looking markings. His exercise tolerance was vastly improved and he returned to his work as a master butcher long before the tube was removed from his empyema.

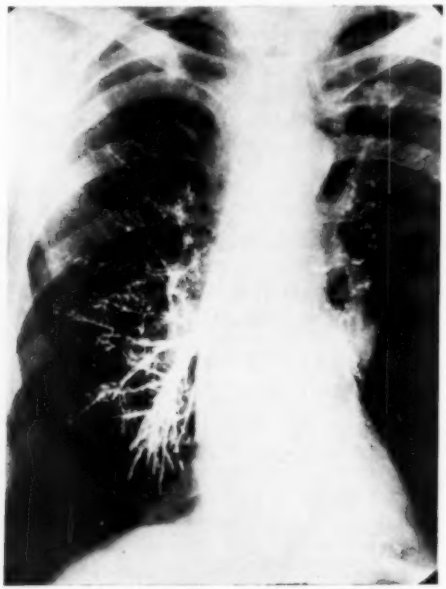


FIG. II. Bronchogram in a patient with bullous emphysema showing displacement of bronchi by huge emphysematous spaces. The very large space on the left side, partly cut off in the picture, is not a pneumothorax.

All went well for four years. Then his respiratory reserve began to deteriorate markedly again and the spaces in his left lung were seen to be increasing in size. In another year his left lung had about half "vanished." and he was again unable to work. He and his family asked for operation on the left side and the spaces on this side were partly excised and oversewn and partly plicated. There were no serious complications and he again returned to work though he was not so active as after the first operation. This was a year ago. He is now 58 and still leading a comfortable, though restricted, life and doing light work. No doubt his generalized emphysema will continue to progress slowly as emphysema usually does and he is probably unlikely to survive more than a few years, but each operation has added useful, happy years to his life.

The success in the first operation in this patient with excision of the outer walls of spaces without suture led me stubbornly to persist with this method in 7 other cases before I accepted the fact that the very high mortality and morbidity (Table 2) was quite unjustified, even in such desperate cases. Only 1 of the 8 patients had no serious complication and 3 died. In fairness to Mr. McConchie it should be stated that these 8 cases were all mine. I now think it is wiser always to leave as complete a pleural covering as possible, using excision and suture where practicable and plication for the remainder. Deformity of the lung is inevitable, though one tries to arrange the lines of suture so as to minimize it. In the 19 operations done in this way there were no deaths and 4 serious complications.

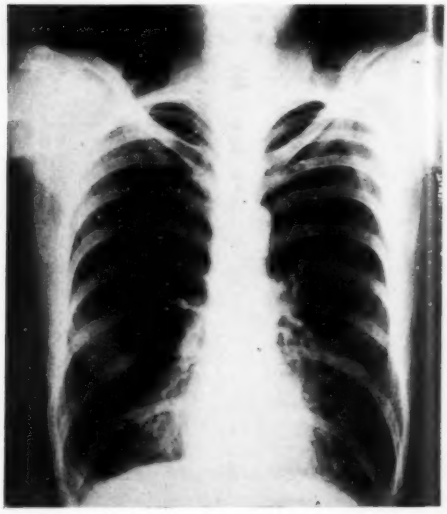


FIG. III. Pre-operative film of a woman aged 45 with bilateral bullous emphysema, worse on the right side. The shadow to the right of the heart with an oblique linear lower margin was found at operation to be due to a massively collapsed middle lobe which reinflated as soon as the pressure by huge bullae in the upper lobe was removed.

Table 2 shows that, apart from 1 death from respiratory failure (this patient only survived twelve hours), all the complications were infective. The air passages in these patients are never completely free of low grade infection which almost invariably flares up after operation. Clinically it seems to start as a violent purulent bronchitis and bronchiolitis, evident within two days of operation, and, if not effectively controlled, it spreads to the lung tissue producing bronchopneumonia within another day or

two. Post-operative management is therefore very difficult in these patients. They are usually emaciated, often have vitamin deficiencies and in general are extremely poor surgical and anaesthetic risks. The careful pre- and post- operative treatment necessary if success is to be achieved has been well described by Newman and his colleagues (1956).

FIG. IV. Pre-operative film of a woman aged 53. At operation the emphysematous lesion was found to be a huge single cyst which had twisted on its pedicle so much that torsion of part of the left upper lobe had occurred so that it could not inflate. This was responsible for the shadow near the hilum.

The results amply justify the effort. All 24 of our 27 patients who survived had improved exercise tolerance once their post-operative troubles were over and in some the improvement was dramatic. These are some of the most grateful patients a thoracic surgeon has. To be rescued from the living death of slow suffocation and become a useful member of society again when all hope had been abandoned must be a very remarkable experience. Admittedly the clock has only been put back and in a few years they will probably be victims of respiratory incapacity again, but the reprieve is well worthwhile.

Such gratifying results can only be achieved if the cases for surgery are carefully selected. They must be severely incapacitated by dyspnoea and it must be proved that the emphysema is of the bullous type with considerable displacement and compression of lung tissue which the operation can relieve. With experience in interpreting the bronchovascular markings in plain films in these cases one learns to detect evidence of displacement and compression. If there is any doubt, a bronchogram resolves it at once (Fig. II). Evidence in serial films of increasing inflation of bullae is a strong indication for operation, especially when there is mediastinal displacement due to the inflation.

FIG. V. Pre-operative film of a man aged 58 with bullous emphysema at both apices, worse on the right. The compressed bronchovascular markings at both bases are readily seen. At right thoracotomy the opacity in the right midzone was unexpectedly found to be due to a carcinoma.

Opacities in the compressed part of the lung may be difficult to interpret correctly (Figs. III, IV and V). In these 3 patients 3 rather similar opacities were found to be due respectively to massive collapse of the middle lobe, torsion of part of the left upper lobe and a bronchogenic carcinoma.

This last case, a man of 58, is included here because his operation was done for emphysema, the shadow of the carcinoma being mistakenly supposed to be due to collapse and infection in part of the compressed lung. When the firm lesion was felt at operation in the bronchus of the posterior segment of the right upper lobe which was also the segment containing nearly all of the huge spaces, this segment was removed. On section a squamous carcinoma was found. He is still well eighteen months later. There is no evidence of recurrence of the carcinoma and he is still less breathless than before the operation.

The one lobectomy in the series was done nine years ago for chronic pneumothorax before it was realized that the spaces could be dealt with and the lobe saved.

The 2 patients with huge single air cysts form the last group in our series. The operation is extremely simple. One clamp is usually enough to occlude the whole pedicle. The only point of interest is that the radiographic appearance of a giant air cyst in an adult is often indistinguishable from that of huge emphysematous spaces. In the patient whose film is illustrated in Fig. IV, I expected to find large spaces and was pleasantly surprised to discover only a huge single pedunculated cyst.

SUMMARY

Large inflated areas in emphysema are always at lobar surfaces. To avoid confusion they are all called emphysematous bullae and are subdivided into emphysematous cysts and blebs which are largely excrescences added to the surface of a lobe and emphysematous spaces which are inflated areas within the superficial part of the lobe. The time-honoured term bullous emphysema is retained for emphysema in which large inflated areas occur.

No matter how large bullae become, they have always arisen from small volumes of superficial lung tissue. The remainder of the lung is compressed but it is frequently capable of considerable useful function if the compression is relieved.

Lung compression may be caused by air trapped in a chronic or recurrent spontaneous pneumothorax or in large bullae. The aim of surgery in emphysema is to relieve the compression by permanently removing the trapped air. The indication for operation may be chronic or recurrent pneumothoraces, often in patients under 40 with little or no generalized emphysema, or large bullae aggravating the dyspnoea in patients usually over 40 with severe generalized emphysema. The latter group may also have pneumothoraces.

The surgical treatment and results in a series of 73 operations for emphysema are described.

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INTESTINAL PERFORATIONS

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DIAGNOSTIC difficulties and mistakes may occur even with the common and familiar intestinal perforations due to peptic ulcer, appendicitis and colonic diverticulitis but are to be expected with those due to rare and unfamiliar causes.

Perforation of the intestine results in local or general peritonitis, the severity of the reaction varying with the site of perforation and the extent of peritoneal contamination. The correct diagnosis may be suggested by the history and mode of onset, but is not always recognized, and although a perforation is diagnosed its site is not revealed until the abdomen is explored. In such an event, a knowledge of the possibilities will aid the surgeon in his search for the lesion.

The purpose of this paper is to enumerate the less familiar causes of intestinal perforation and to discuss their diagnosis and management with illustrations from a series of cases under the care of the author.

General Pathology

Intestinal perforation may be partial or complete. When partial, either mucosal ulceration occurs from within or seromuscular splitting from without. The former commonly results from inflammatory lesions, the latter from trauma or distension. Either type can progress to complete perforation with ensuing local or general peritonitis. In cases of complete perforation the extent of the peritonitis is governed by the site and the speed of the perforation. A freely leaking jejunal perforation will cause a general peritonitis; whilst the slow perforation of an inflamed colonic diverticulum is more likely to result in a local abscess or a fistula.

The four basic pathological processes which may result in intestinal perforation are:

Trauma,
Inflammation
Necrosis,
Distention.

Usually two or more of these factors work in combination as, for example, when the bowel proximal to an intestinal obstruction becomes so distended that its blood supply is impaired with resultant necrosis and perforation.

Clinical Classification and Discussion

The following classification of causes of intestinal perforation has been found of clinical value.

1. Closed trauma.
2. Open trauma.
3. Swallowed foreign bodies.
4. Inflammation.
5. Intestinal obstruction.
6. Neoplasm.

Each of the above groups is discussed with illustrative case histories.

1. *Closed trauma*

Into this group fall cases of intestinal perforation caused by direct or indirect abdominal injury which does not result in an abdominal wound. Such perforations may be caused in various ways.

(a) Non-penetrating abdominal injury most commonly results in damage to the liver or spleen as these are fixed viscera which cannot move far from the path of an injuring force. If intestinal perforation occurs, the small gut is involved in 90 per cent. of cases. The upper jejunum, lower ileum or gut tethered by adhesions is most liable to injury—once again, these are relatively fixed viscera. In the majority of cases the involved gut is crushed between the injuring force and the spinal column although sometimes the intestine may be burst by a sudden rise in intra-abdominal pressure. If the abdominal muscles are tensed at the time of the injury, a simple abdominal contusion is the likely result: it is when they are relaxed that visceral damage occurs, often with minimal bruising of the abdominal wall.

(b) Indirect violence may also result in closed intestinal injury as instanced by intestinal perforation which follows a fall from a height.

(c) Blast injuries are a specialized type of indirect abdominal injury most common in war. The majority of the cases result from immersion blast whilst the victim is swimming, but close proximity to an air blast will have a similar effect. Retroperitoneal and intramural intestinal haemorrhages are invariable and in severe cases intestinal perforation occurs, either primarily or some hours later. The large gut is most vulnerable to this injury.

(d) The presence of an inguinal hernia, especially right sided, increases the liability to intestinal injury following a blow on the abdomen. The lower ileum is usually ruptured, as a result of either:

(i) a bursting force arising when increased intra-abdominal pressure is directed into the unsupported hernial sac; or

(ii) direct injury to gut contained in the hernial sac.

Symptoms of intestinal rupture may be delayed until gut contents have leaked from the hernial sac into the general peritoneal cavity. The patients involved are always males. Femoral hernia does not predispose to similar injury (Aird, 1937).

(e) Muscular effort by increasing the intra-abdominal pressure, is known to be a cause of intestinal rupture. Straining on heavy lifting, micturition or defaecation is prone to have this result in susceptible individuals. Especially is this the case when the subject has an inguinal hernia. The ileum is most commonly involved, but rectal perforation may follow exertion in subjects with rectal prolapse, especially women (Wilensky and Kaufman, 1937).

Illustrative cases

Case 1—Jejunal tear following non-penetrating abdominal injury

A man of 40 was admitted to hospital on 8th March, 1949. Four hours previously he had been struck in the left loin by a steel prop. Within the hour central abdominal pain had developed and was gradually increasing in severity.

On examination. Pale. Pulse 80, good volume. Abdomen — bruising in the left hypochondrium. Board-like rigidity. Absent bowel sounds. A diagnosis of perforated abdominal viscus was made.

Laparotomy. Much turbid free fluid was present. A rent 2.5 cms. long was found in the antimesenteric border of the jejunum 45 cms. from the duodeno-jejunal flexure.

The defect was closed transversely in two layers with continuous catgut, and the abdomen closed, with drainage.

Post-operatively gastric aspiration and intravenous fluids were employed until bowel sounds returned. The patient made an uncomplicated recovery.

Comment. In this case symptoms developed early and diagnosis presented no difficulty as signs of general peritonitis were present from the first.

Case 2—Ileal tear following non-penetrating abdominal injury

A man of 54 was admitted to hospital on 30th December, 1948, having been struck in the lower abdomen forty-eight hours previously by a piece of wood. Initially there was no pain but thirty-six hours after the injury a constant abdominal ache developed and gradually increased in severity. It was confined to both iliac fossae and was worse on movement. The patient had vomited and his bowels had last acted twenty-four hours before admission.

On examination. Ill and pale. Temperature 98. Pulse 88. Tongue furred. Marked halitosis. Abdomen — distended. Contusions in the hypogastrium and the right iliac fossa. The lower abdomen was tender and rigid. Bowel sounds infrequent. Tender per rectum.

A diagnosis of ruptured ileum was made.

Laparotomy. There was much brown free fluid and a plastic peritonitis. A tear 1.25 cms. long was present in the antimesenteric border of the ileum 90 cms. from the ileo-caecal junction. It was partially sealed by fibrin.

The tear was closed transversely in two layers with catgut and the abdomen was closed with drainage.

Post-operatively the patient was treated with drip and suction until bowel sounds returned. Intramuscular penicillin and intravenous soluthiazole was given. He developed a pelvic abscess which was drained per rectum on 21st January, 1949, but thereafter he made an uncomplicated recovery and was discharged home on 9th February.

Comment. The delay in the onset of symptoms is noteworthy and must be accounted for either by early sealing of the perforation with fibrin and omentum or by later perforation of a previously bruised ileum. Here the symptoms and signs suggested a spreading pelvic peritonitis.

Case 3—Ileal tear. Closed trauma in association with an inguinal hernia

A man of 64 was admitted to hospital on 19th January, 1955, having suffered a blow in the chest and upper abdomen nine hours previously when he collided with a burly individual who was running for a train. Since then he had developed increasing abdominal pain.

On examination. General condition good. Incon-stant general abdominal tenderness. Few bowel sounds. A tender left inguinal hernia with a cough impulse was present.

A diagnosis of abdominal wall contusion was made, and the patient watched.

Four hours later the pain had increased and the patient was sweating. There was generalized lower abdominal rigidity maximal in the right iliac fossa. Bowel sounds were absent. The left inguinal hernia was still tender. Rupture of the ileum was diagnosed.

Laparotomy revealed free peritoneal fluid and fibrin-covered small bowel. A ragged tear was present in the antimesenteric border of the upper ileum. About the site of the tear were some old adhesions giving the impression that this part of the bowel had originally been contained in the hernial sac. The injured bowel was resected and end to end anastomosis performed. The hernial sac was excised from within the abdomen and the wound closed without drainage.

Following operation the patient was treated with drip, suction and terramycin and apart from a deep venous thrombosis in the left leg, made a good recovery.

Comment. The ileal tear in this case was probably due to a bursting force arising in the gut contained in the hernial sac. The early physical signs suggested a simple bruising of the abdominal wall. Obvious peritonitis developed later when faecal fluid leaked from the hernial sac into the general peritoneal cavity. The most significant changes during observation were the increase in pain and loss of bowel sounds.

Case 4 — Rectal perforation following muscular effort

A man aged 28 was admitted to hospital on 16th September, 1949. He had a long history of dyspepsia and eight hours before admission whilst working at the coal face was struck by sudden severe abdominal pain and pain in the right shoulder. He had vomited copiously since the pain began.

On examination. General condition good. The abdomen was board-like and bowel sounds were absent. There was marked peritoneal tenderness on rectal examination.

A diagnosis of perforated peptic ulcer was made.

Laparotomy revealed a gross offensive peritonitis which was eventually found to be due to a 2.5 cm. perforation in the anterior wall of the rectum 2 cms. above the peritoneal fold. There was no evidence of new growth or foreign body. The stomach and duodenum were normal. The perforation was closed over an omental graft and the abdomen closed with drainage. No colostomy was fashioned.

Convalescence was complicated by a sub-phrenic abscess which was drained after resection of the 12th rib, and a lung abscess in the right upper lobe which resolved on postural drainage. The patient eventually made a complete recovery.

Comment. In the absence of any other obvious cause it is probable that in the above case the rectum ruptured whilst the patient was workng at the coal face — work which involves considerable physical strain. In this case there was no evidence of rectal prolapse. The rectal tear was only found after considerable search although a lesion of the large gut should have been suggested immediately by the offensive B. coli nature of the peritonitis. Exposure was good and closure of the tear straight forward and for this reason a colostomy was thought unnecessary. It is doubtful whether colostomy would have prevented the post-operative complications.

2. *Open trauma*

A discussion of the results of open abdominal trauma is pertinent because the lessons learnt as a result of war surgery need constant reiteration if they are not to be forgotten.

In the majority of cases, intestinal perforation resulting from open trauma follows gunshot or stab wounds. Multiple perforations of the gut are more common than is the case with closed trauma; so also are associated visceral injuries. It is well to remember that the wound need not be confined to the anterior abdominal wall to result in gut damage. Wounds in the loin and buttock may have a similar effect. High velocity missile wounds of the buttock frequently result in perforation of the abdominal or pelvic viscera.

In World War II, of all abdominal wounds, 30 per cent. resulted in small gut perforation with a mortality of from 25 to 50 per cent., and 30 per cent. caused large gut perforation with a mortality varying between 10 and 70 per cent. in selected series.

In these cases there are always two lesions to be considered — that of the abdominal wall and that of the intestine. The wound of the abdominal wall may be a simple stab or puncture, a through and through bullet

wound or a large tissue defect with prolapsing bowel. The intestinal wound may be single or multiple and varies in severity between a small perforation and a segment of completely tattered, blasted gut, with or without accompanying mesenteric injury. At operation, treatment of the intestinal wound demands priority.

Illustrative cases

Case 5 — Ileal and colonic perforations following abdominal gun-shot wound

A female aged 36 was admitted to hospital on 17th November, 1950, having been shot in the abdomen three hours previously.

On examination. Shocked. Pulse imperceptible. Systolic blood pressure 40 mm. of mercury. Mucous membranes pale. Through and through gun-shot wound of the lower abdomen with entry in the upper right buttock and exit in the left iliac fossa. Intravenous infusion of 500 ccs. of plasma and 750 ccs. of blood given in thirty minutes raised the blood pressure to 110/90 mm. of mercury.

Laparotomy. The abdomen was full of blood. There were multiple rents in the mid-ileum and two mesenteric tears at the same level. This area was resected and end to end anastomosis performed. A further wound in the upper ileum and two in the pelvic colon were sutured transversely with continuous catgut in two layers. No colostomy was performed. The abdomen was closed with interrupted catgut, and drained through a separate stab wound.

A further 1,000 ccs. of blood and 1,000 ccs. of plasma were given during and after operation. Recovery was uneventful.

Comment. As in many of these cases, vigorous resuscitation was necessary and operation was undertaken when the blood pressure rose to over 100 mm. of mercury. Numerous perforations in the mid-ileum made resection preferable to multiple simple closures. Simple suture of the pelvic colon was successful, without the need for colostomy or exteriorization.

Case 6 — Jejunal and colonic perforations following abdominal gun-shot wound

A young male was admitted to hospital on 11th February, 1951, having sustained a gun-shot wound of the abdomen forty-two hours previously.

On examination. His condition was good. Blood pressure 120/90 mm. of mercury. There was obvious general peritonitis. There was an entry wound in the left mid-abdomen and an exit wound in the left loin.

Laparotomy revealed six holes in the jejunum and one in the transverse colon. There was little free fluid, for all the perforations were partially sealed with fibrinous exudate.

All wounds were closed in two layers transversely and a transverse colostomy with spur fashioned proximal to the colonic wound. The abdomen was closed with drainage.

During and after operation 2,250 ccs. of blood were given. The patient died of shock and toxaemia eighteen hours after operation despite further transfusion.

Comment. Fibrinous reaction round the perforations had prevented gross peritoneal soiling and maintained the patient in good condition despite the time lag between wounding and operation. With non-operative treatment, drip and suction, it is conceivable that this man would have survived.

Case 7 — Colonic and bladder perforation following mortar wound of buttock

A young male was admitted to hospital on 19th January, 1952, having been wounded by a mortar shell six hours previously. His left buttock had sustained the major injuries.

His systolic blood pressure was 150 mm. of mercury on admission but suddenly fell to 70, while at the same time signs of intra-abdominal visceral damage developed. The patient was rapidly given 1,000 ccs. of blood through two drips. As a result, his blood pressure climbed to 100 mm. of mercury and he was taken to the operating theatre.

Laparotomy revealed 1,500 ccs. of blood and faeces in the peritoneal cavity. There was a through and through wound of the sigmoid colon, a penetrating wound of the bladder fundus and a tear of the pelvic mesocolon. The bladder contained the shell fragment which was removed. The wounds were sutured, a transverse colostomy performed and an indwelling urethral catheter left in place. During and after operation 5,500ccs. of blood were given.

Post-operatively the patient was treated with drip and suction, streptomycin and penicillin. His abdominal wound burst on the fifth day and was re-sutured. After this the patient made a good recovery. On 11th March, 1952, his colostomy was resected and an end-to-end colonic anastomosis performed.

Comment. This case emphasizes that a buttock wound can result in intestinal injury. Rapid and massive transfusion through *two drips* was life saving and raised the blood pressure satisfactorily. Transverse colostomy was performed in view of the severe faecal contamination of the peritoneal cavity. This contamination caused the ileus which was contributory to the wound dehiscence, a well recognized complication in these cases.

Case 8 — Stab wound of caecum

A child of three was admitted to hospital on 23rd October, 1950, having been stabbed in the abdomen two hours previously. His general condition was good. Examination revealed a stab wound

in the right iliac fossa emerging in the right loin. An intravenous glucose saline drip was started before operation.

Laparotomy revealed a through and through wound of the caecum. The caecal exit wound was extraperitoneal and was approached by incising the lateral peritoneum. Both wounds of the caecum were closed in two layers with catgut. The abdomen was closed with drainage through the loin.

Post-operatively the patient did well for thirty-six hours and then died suddenly.

Post-mortem revealed a spreading cellulitis in the retroperitoneal tissues.

Comment. The necessity for looking for and closing extraperitoneal perforations of the large gut is emphasized although in this case the treatment was unsuccessful. Caecostomy would have been advisable to ease pressure on the suture lines.

3. *Swallowed foreign bodies*

These can cause intestinal perforation from within the bowel lumen.

Non-dietary foreign bodies, e.g. pins, when swallowed, usually alarm the patient sufficiently to bring him to medical care. It is the dietary foreign bodies, e.g. rabbit bones, swallowed unknown to the patient, that may cause unexpected intestinal perforation and diagnostic difficulty.

Perforation follows impaction. This occurs rarely in the small gut unless there is a Meckel's diverticulum or a large hernia. Impaction in the large gut occurs in the caecum or at the flexures (Wade, 1952). At the site of impaction the foreign body may cause areas of necrosis and perforation. It may work its way through the intestinal wall into the general peritoneal cavity but more commonly disimpacts and passes on. Even in the latter event, however, local necrosis may proceed to perforation.

A free small intestinal perforation results in general peritonitis but as a rule perforation is more gradual giving rise to local peritonitis or an inflammatory lump. More bizarre results of intestinal perforation consequent on the ingestion of foreign bodies are haemorrhage and obstruction by bands.

Illustrative cases

Case 9 — Perforation of ileum by a piece of wire

A man of 54 was admitted to hospital on 22nd April, 1949. He was complaining of pain in the left iliac fossa which had become severe during the last four hours. He had vomited and had noticed increasing abdominal distension. He had been absolutely constipated for twenty-four hours.

On examination. Temperature 97. Pulse 88. General condition good. The abdomen was distended and there was tenderness in the left iliac fossa. Bowel sounds were increased. Rectal examination was negative. Two enemata produced no result.

A diagnosis of intestinal obstruction was made.

Laparotomy revealed distended small bowel. The upper ileum was obstructed by an adhesion which had formed to a piece of wire perforating the bowel wall. The adhesion was divided, the wire removed and the perforation oversewn.

The patient made an uncomplicated recovery.

Comment. In this case the actual intestinal perforation was minute and symptomless but nevertheless eventually caused the obstructing adhesion. The patient could not account for the presence of the wire in his alimentary canal.

Case 10 — Perforation of the caecum by a rabbit bone

A man of 60 was admitted to hospital complaining of mid-abdominal pain. He had slipped on the morning of admission and soon afterward noticed discomfort in his left inguinal hernia. He had vomited, and when seen had severe generalized abdominal pain.

On examination. The lower abdomen was tender. Bowel sounds were infrequent. Left inguinal hernia reducible but tender. Rectal examination was negative.

Laparotomy. Thin purulent fluid in the lower abdomen, with a mild peritonitis of the surrounding gut. A rabbit bone 2.5 cm. long and 2 mm. wide was found free in the peritoneal cavity in close relation to the medial aspect of the caecum. There was no obvious mass or exit wound in the caecum. Normal small bowel was found in the hernial sac. No other lesion was found to account for the peritonitis which was considered to be due to an undiscovered perforation of the gut caused by the rabbit bone. The bone was removed and the abdomen closed with drainage.

Post-operatively the patient was treated by drip, suction and antibiotics. He had a small pulmonary embolus but apart from this made an uncomplicated recovery and was discharged fit.

Comment. The history of having slipped just before the onset of abdominal pain was probably coincidental. The absence of a discoverable perforation of the gut is surprising but may be accounted for by the small dimensions of the rabbit bone. In such a case drainage of the abdomen is of first importance.

Case 11 — Chronic perforation of the rectum by a fish bone

A man of 54 was admitted to hospital with a five-day history of diarrhoea, epigastric discomfort and nausea. There had been blood in the stools.

On examination. The lower abdomen was tender and there was a mass in the left iliac fossa. Rectal examination revealed an indurated anterior rectal wall.

A clinical diagnosis of rectal carcinoma was made but the patient refused laparotomy until two months later.

Laparotomy. There was a large induration in the anterior wall of the middle third of the rectum and a fish bone was found free in the recto-vesical pouch.

The bone was removed and the patient made an uncomplicated recovery.

Comment. The necessity for biopsy of every suspected case of rectal carcinoma is emphasized.

4. *Inflammation*

There are numerous causes of inflammatory intestinal perforation but in all cases the pathological process is similar. Initial mucosal ulceration is followed by involvement of the other intestinal coats. In severe cases necrosis is caused by a combination of inflammatory endarteritis and toxic degeneration and this eventually leads to perforation. The commonest example of this process is seen in the perforation of a peptic ulcer.

(a) Peptic ulcer occurs in less common sites than the stomach and duodenum and may be the cause of true intestinal perforation. An ulcer sometimes arises on the efferent jejunal loop following partial gastrectomy or gastro-jejunostomy and is prone to perforate, being relatively unsupported.

(b) Primary simple ulcer occurs on the antimesenteric border of the jejunum, or more rarely, the ileum. It is not a true peptic ulcer, nor is it due to a specific infection, but is important in this discussion, for in many cases, its first manifestation is perforation. Such perforation may follow abdominal trauma.

(c) Meckel's diverticulum is the site of ectopic gastric mucosa in 16 per cent. of cases. This may line the tip or the whole of the diverticulum and can cause peptic ulceration in the adjacent intestinal mucosa usually at the base of the diverticulum. Such an ulcer may perforate, 85 per cent. of cases occurring in children under the age of 16. The majority of cases occur in males and the perforation is often preceded by melaena (Hancock, 1951).

Perforation in a Meckel's diverticulum is also caused by simple inflammation, the consequence of stagnation followed by stercoral ulceration and infection.

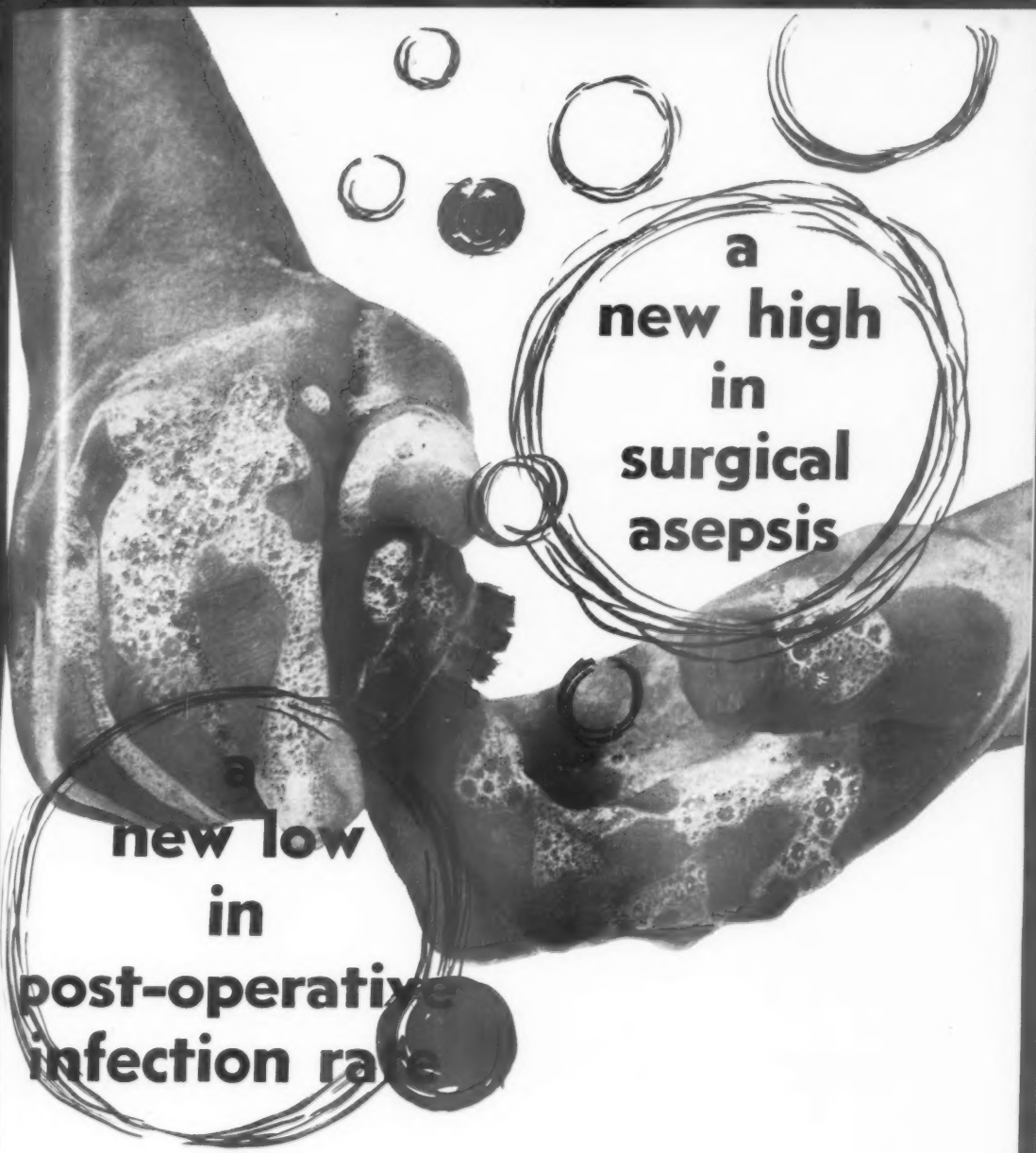
(d) Diverticula occur elsewhere in the intestinal tract and are liable to inflammatory perforation. Those most commonly involved are found in the descending and pelvic colon. Jejunal diverticula are also liable to inflammation and perforation (Milnes Walker, 1945). Like the colonic variety, jejunal diverticula are usually acquired, but whilst perforation of a colonic diverticulum often results in a local abscess, perforation of a jejunal diverticulum causes a general peritonitis. In both cases the condition is commonest after middle age.

(e) Non-specific inflammation is probably the cause of a group of allied diseases involving the small and large intestine, all of which may result in inflammatory perforation in the acute stages. Included in this group is jejunitis, regional ileitis (Crohn's disease) and ulcerative colitis.

(f) Specific inflammation. Typhoid fever still occurs in Great Britain. In 1947, 275 cases were recorded in England and Wales. The ileum perforates in 3 per cent. of cases (Lakin, 1951) but occasionally the caecum or ascending colon is involved. Such perforation accounts for 30 per cent. of the deaths attributable to the disease. Perforation occurs during the third week and may be preceded by severe haemorrhage. Even if laparotomy is undertaken only 10 per cent. of cases have up to the present survived although the introduction of chloramphenicol as a specific treatment will probably lower the frequency of perforation and improve the chances of survival should it occur.

Tuberculous ulceration of the ileum occasionally occurs in severely ill sanatorium patients. Perforation rarely results, usually as a terminal phenomenon.

Necrotizing jejunitis is a doubtful entity but is regarded by Fick and Wolken (1949) as a specific infection. It causes extensive jejunal ulceration which commonly leads on



Is your post-operative infection rate as low as this?

1.2 per cent. infections among 6,242 cases.[74]
0.9 per cent. infections among 561 cases.[3]
0.6 per cent. infections among 1,211 cases.[74]
0.7 per cent. infections among 296 cases.[74]

If not, you will be vitally interested in.....

NEW Sudsing Detergent Revolutionises Scrubbing Technique

STERILISES HANDS AFTER 3-MINUTE SCRUB

pHisoHex – New Sudsing Detergent supersedes soapwash – saves time

Results of approximately five years' experience with pHisoHex at the Harvard Research Laboratories are summarised by Walter.[23]

"the disinfecting action . . . is so rapid that a two-minute pre-operative scrub is bacteriologically feasible."

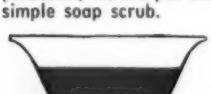
Hands washed with pHisoHex will often be found to be sterile, not just surgically clean, when attempts are made to culture organisms. In one series of tests all resident and transient skin bacteria were eliminated in *54 per cent. of users.*[24] The bactericidal power of pHisoHex has also been demonstrated by repeated failure to cultivate bacteria from the rinse water after washing is completed.[22]

pHisoHex provides far superior disinfecting action

The superiority of pHisoHex over hospital soap as a skin antiseptic has been proved by Dull and co-workers.[9] They add minute amounts of pHisoHex to basins of "dirty" wash water obtained after a simple soap scrub. pHisoHex in a dilution of 1:2000 eliminated almost 80 per cent. of the bacteria in the wash water compared with the growth in control basins. In dilution of 1:1000, bacterial growth in wash water was completely inhibited.

Approximately 80% inhibition of bacterial growth.

pHisoHex, 0.5 ml. per litre of wash water obtained after simple soap scrub.



100% inhibition of bacterial growth.

pHisoHex, 1 ml. per litre of wash water obtained after simple soap scrub.

pHisoHex – Safer for the skin

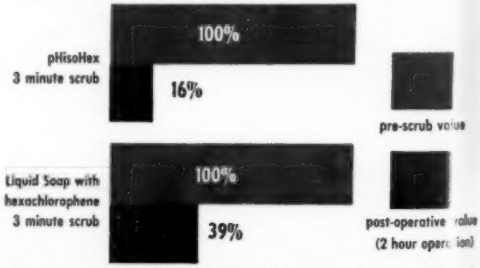
All investigators of pHisoHex concur as to its safety. Not only has *"a striking lack of skin irritation"*[26] been noted, but no brush is needed [2,24,26,27] and *"hence less dermatitis and few tender hands . . . as compared to those following the usual soap and brush scrub technique."*[24] In over a year, Thirlby and Nesbit[26] *"encountered no instances of apparent sensitivity."* On the contrary *"several surgeons who had mild dermatitis and tender hands from 'brush' scrubbing observed their hands to be less tender and the dermatitis healed."*[24]

Comparison Tests prove pHisoHex halves bacterial skin populations

Tests comparing efficacy of soap containing hexachlorophene with pHisoHex reveal significant differences.[2] The simple addition of hexachlorophene to soap will of course reduce the bacterial skin population immediately after scrubbing. However, pHisoHex, a synthetic, sudsing emollient detergent plus hexachlorophene, reduces bacterial population to less than half of that obtained with the soap-hexachlorophene combinations.[10] pHisoHex has the same pH as normal skin, thus is non-irritating, non-sensitising, and hypoallergenic.

Dull, Zintel et al.,[9] of the Harrison Department of Surgical Research, University of Pennsylvania, have determined that liquid soap containing hexachlorophene is only half as effective in *maintaining* surgical hand cleanliness as pHisoHex *at the end of a two-hour operation.*

Comparison of antibacterial effects at end of 2 hours of 3-minute scrub with pHisoHex and 3-minute scrub with liquid soap containing hexachlorophene.



The number of bacteria obtained on culture of hands prior to scrubbing with either agent is represented by 100 per cent.

Here's the Important Difference!

The difference between pHisoHex and liquid soap containing hexachlorophene can be accounted for, in part, by the presence of emollients in pHisoHex which adhere to skin causing the antiseptic to exert a continuous action and forming an antiseptic "invisible glove."

pHisoHex

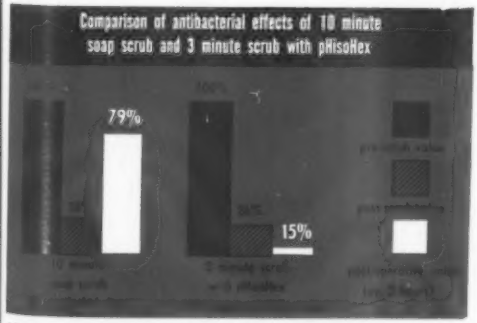
reduces infection rate by 75%[2]

How pHisoHex reduces post-operative infection rate

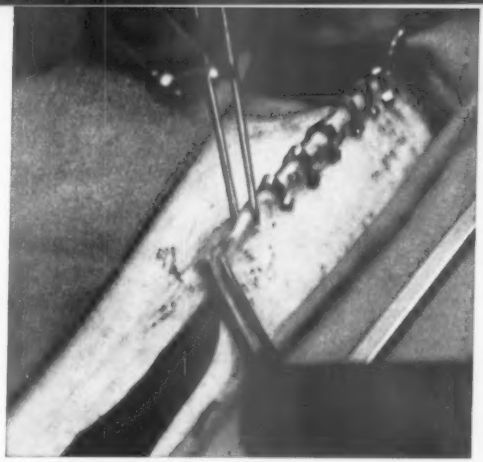
During a one-year period in which pHisoHex was used both as a surgeon's "hand prep" and for pre-operative preparation of the patient's skin, it has *"maintained a low rate of post-operative wound infections due to skin bacteria"*—1.85%.[2] In another series of cases studied by Bowers,[27] the infection rate among 1,500 clean cases was 1.6%, and among 430 *"potentially dirty cases"* only 3.95%. This investigator[27] comments that it *"seems logical to assume that the scrubbing technique (with pHisoHex) is sound if a large number of potentially dirty cases can be performed with an infection rate no higher than 3.95%."*

Here's how pHisoHex prolongs Antisepsis, inhibits bacterial growth during and after operation

Because hexachlorophene is adsorbed by the skin, *"exerting a constant . . . effect on the resident flora"*[29] it has a prolonged antiseptic action. By contrast, a ten-minute soap scrub has an evanescent effect as shown in the following graph.[9]



The number of bacteria obtained on culture of hands prior to scrubbing with either agent is represented by 100 per cent. Following soap scrub, bacteria regenerate beneath operator's gloves.[18] At end of two-hour operation, hands carry only 21 per cent. less bacteria than before soap scrubbing. Following a pHisoHex scrub, bacteria decrease progressively during the operation because of its continuous antibacterial action.



If used exclusively each day, pHisoHex will remove virtually all bacteria[25]

After three or four days of such use, hand cultures usually reveal *"no growth or only a rare colony"*[22] showing that *"the antiseptic protection"* . . . extends over a period of several days.[26]

Advantageous for preparing the operative site

Unlike iodine and mercurial skin antiseptics, pHisoHex is non-irritating and hypoallergenic;[76] unlike soap it contains no damaging alkali or fatty acids.[76, 77, 80, 81] These characteristics, as well as its *"most rapid disinfectant action"* [17] and its *"pH which approaches that of skin,"* [22] make pHisoHex especially valuable for pre-operative preparation of the patient's skin. It not only *"provides optimum disinfection in areas where atraumatic technique is desirable,"* [23] but also forms a protective film.[16]

HOW SUPPLIED

For best results and economy, pHisoHex is supplied in 5 fl. oz. pliable plastic containers.

SIMPLE TO USE

DIRECTIONS for surgical scrub or wash: Wet the hands and forearms. Apply a few drops of pHisoHex and, with additional small amounts of water, work into a lather for a quick 30-second preliminary *washing*. Rinse. Apply from 2 to 4 ml. and scrub or wash for 2 minutes. *Always add small amounts of water* during the preparation. This develops more suds and assists in the detachment of soil. Rinse thoroughly. Only 2 ml. for a 2-minute wash is now the routine in many hospitals, but it is unrealistic and inadvisable to recommend *one* technique of prepping under *all* conditions for *all* users.

Zalkon chloride aqueous solution, 1:1000, may be used as a soak, *after thorough rinsing*, if a more immediate bactericidal action is required by emergency. However, the use of agents not containing hexachlorophene may reduce the cumulative antibacterial effect obtained with the exclusive use of pHisoHex.

pHisoHex has a clinically proven background of effectiveness in thousands of cases reported in more than 80 published studies

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to perforation. The recommended treatment in such cases is resection with post-operative antibiotics.

Ascaris infestation is a known cause of acute appendicitis with perforation and occasionally results in small gut perforation. Such a perforation is not strictly inflammatory but rather due to local digestion of the intestinal wall by the worm or its toxic products.

Illustrative cases

Case 12 — Perforated ulcer in a Meckel's diverticulum

A woman of 46 was admitted to hospital on 9th July, 1950, with a four-day history of intermittent generalized abdominal pain. She had vomited. Bowels and periods were normal.

On examination. The patient was ill. The abdomen was distended and tender with generalized guarding. Bowel sounds were absent. There was tenderness on rectal examination, especially on the right.

A diagnosis of acute appendicitis with peritonitis was made.

Laparotomy revealed free pus in the abdomen. The appendix was normal but 60 cms. from the ileo-caecal junction was a wide-mouthed Meckel's diverticulum 5 cms. long. At its apex was a perforation 1.5 cms. in diameter. The diverticulum and 5 cms. of the bowel either side were resected and end to end anastomosis performed. The appendix was removed, and the abdomen was closed with drainage.

The patient made an uneventful recovery. Microscopic examination revealed ectopic gastric mucosa in the diverticulum with ulceration at the site of perforation.

Comment. This is a case of perforated peptic ulcer in a Meckel's diverticulum. The similarity to a case of acute appendicitis with peritonitis should be noted.

Case 13 — Perforation of a jejunal ulcer

A man of 45 was admitted to hospital on 9th January, 1949, with an eleven-hour history of severe abdominal pain of sudden onset. He had vomited. Bowels and micturition normal. He gave a previous history of mild indigestion.

On examination. The patient was in severe pain. The tongue was dry and the pulse rapid. The abdomen was board-like. Liver dulness was reduced and bowel sounds absent.

A diagnosis of perforated peptic ulcer was made.

Laparotomy. Much free fluid. No abnormality of stomach or duodenum. A 1.25 cm. perforation was found in the antimesenteric border of the jejunum 60 cms. from the duodeno-jejunal flexure. At this spot a shallow ulcer was palpable.

The perforation was closed transversely in two layers with catgut and a free omental graft applied. The abdomen was closed with drainage.

Post-operatively the patient was treated with drip, suction and penicillin. He made an uncomplicated recovery.

A barium meal and follow through on 23rd March, 1949, showed no abnormality.

Comment. Although a biopsy was not performed, this case is regarded as a perforation in a simple jejunal ulcer. It was impossible to differentiate pre-operatively from a perforated gastric or duodenal ulcer.

Case 14 — Jejunitis with perforation

A man of 56 was admitted to hospital on 27th May, 1956, with an eleven-hour history of severe intermittent upper abdominal pain. He had vomited. He had suffered from indigestion for one year.

On examination. Temperature 102.2. Pulse 132. In severe pain. Tenderness and guarding in the left hypochondrium and left iliac fossa. Bowel sounds normal. Rectal examination revealed no abnormality.

X-ray of the abdomen showed distended loops of small gut and the patient was submitted to laparotomy as a case of small gut strangulation.

Laparotomy revealed an acute jejunitis. The whole jejunum and only the jejunum was an angry red. The related mesenteric glands were large and fleshy. There was an antimesenteric perforation 0.5 cm. in diameter 70 cms. from the duodeno-jejunal flexure. The rest of the gastro-intestinal tract was normal.

Simple closure of the perforation was performed and the abdomen closed with drainage.

Following operation the patient was treated with drip, suction, penicillin and streptomycin and made an uncomplicated recovery.

There were no pathogens in the faeces and barium meal and follow through on 21st June revealed no abnormality.

Comment. The appearance of the jejunum was similar to that of the ileum in acute regional ileitis and the case is regarded as of similar aetiology. The high fever with a short history is noteworthy.

Case 15 — Perforation of the ileum in typhoid fever

A middle-aged Chinese male was sent into hospital with a vague history of lower abdominal pain and frequency of micturition, both of seven days duration.

On examination. Apart from lower abdominal tenderness and bilateral ectopic testicles, there were no abnormal physical signs.

The patient was kept under observation but after thirty-six hours had a sudden and profuse rectal haemorrhage. A tentative diagnosis of acute bacillary dysentery was made and a course of sulphaguanidine was started as this was the only chemotherapeutic agent available.

During the next twenty-four hours the patient complained of increasing pain in the right iliac fossa and he began to vomit for the first time. His abdomen became board-like and bowel sounds disappeared. It was obvious that he had developed an acute peritonitis and laparotomy was performed forthwith.

Laparotomy revealed a severe generalized peritonitis due to the perforation of two typhoid ulcers in the anti-mesenteric border of the terminal 30 cms. of the ileum. The Peyer's patches of the remainder of the ileum were swollen and congested. The caecum and colon were not obviously involved. The free peritoneal fluid was copious, thin and light brown.

The perforations were rapidly closed in two layers with continuous catgut and the abdomen closed with drainage but despite plasma transfusion the patient died of shock and toxaemia fifteen minutes after operation.

Comment. A regime of intensive chloramphenicol therapy might have prevented perforation. The drug should be given in doses of 4 grams immediately followed by 250 mgm. two-hourly until the fever settles. This phase takes up to four days. Administration should be continued in doses of 250 mgm. four-hourly for a total of eighteen days in order that relapse may be prevented (Lakin, 1951).

Case 16 — Ascaris perforation of the appendix

A male child of three years was admitted to hospital on 2nd March, 1951, with a four-day history of vague fever and cough with loss of appetite. A week previously he had suffered a sharp attack of diarrhoea.

On examination. He was restless. He had a clean, moist tongue. There was generalized abdominal tenderness and guarding. Bowel sounds were absent, and the abdomen was moderately distended. On examination of the rectum an ascaris 20 cms. long was digitally evacuated.

A diagnosis of general peritonitis probably due to a perforated appendix was made.

Laparotomy revealed a mild general peritonitis with a small amount of sero-purulent fluid. Numerous ascarides were free in the peritoneal cavity. Twelve worms were removed in all. The appendix was non-inflamed but on closer inspection was found to have a terminal perforation 0.5 cm. across through which the worms must have escaped as there was no other lesion in the abdomen. The small intestine was noted to be packed with further worms.

Routine appendicectomy was carried out and the abdomen closed without drainage.

Post-operatively the patient made fair progress and was given soluthiazole intramuscularly. During the first twenty-four hours he vomited four further worms. Thirty-six hours after operation, however, he suddenly collapsed and died. No post-mortem examination was allowed.

Comment. The cause of death in this case is not clear. It may have been due to the absorption of toxic products formed by the ascarides in the peritoneal cavity; alternatively further worms may have escaped through the appendicectomy site as it is known that these worms have predilection for passing across apparently sound suture lines.

5. *Intestinal obstruction*

Perforation following intestinal obstruction results from distension, interference with blood supply to the bowel or a combination of both factors. Blood supply can be impaired as a result of distension from within, strangulation of the vessels or direct pressure from without.

Intestinal obstruction is commonly classified as due to

(i) simple occlusion,

(ii) strangulation,

or (iii) neurogenic disturbance—paralytic or spastic ileus.

It is in the first two groups that perforation occurs, and cases of strangulation, and simple occlusion involving the large bowel are most dangerous in this respect.

Perforation may occur

(i) at the site of obstruction due to pressure necrosis,

(ii) proximal to the obstruction,

or (iii) in a closed loop of bowel. If a section of bowel is occluded at both ends, it becomes a closed loop which is prone to perforate early, especially when the bowel contents are infective, as they usually are. Such a condition commonly arises in occlusive lesions of the descending colon when the ileo-caecal valve is competent (40 per cent. of cases). In these cases the caecum is most likely to perforate.

Illustrative cases

Case 17 — Ileal perforation at the site of obstruction

A woman of 36 was admitted to hospital on 19th June, 1949, with a three-hour history of sudden severe abdominal pain. The pain was mainly epigastric but was also referred to the right shoulder. She had vomited. Bowels had been opened normally. She had previously had her appendix removed.

On examination. The patient was collapsed. The abdomen was tender and board-like. No bowel sounds were present. Rectal examination revealed tenderness in the pouch of Douglas.

A diagnosis of general peritonitis was made, the cause being uncertain.

Laparotomy revealed a general peritonitis. The terminal ileum was grossly distended proximal to an obstructing adhesion. A freely leaking ileal perforation was situated 1 cm. above the adhesion. The adhesion was divided and the perforation repaired. The fluid was sucked out and the abdomen closed without drainage.

Following operation the patient was treated with drip, suction and antibiotics and made a good initial recovery. She unfortunately died of a massive pulmonary embolus on the seventh post-operative day.

Comment. There was nothing to suggest a pre-existing intestinal obstruction in this case, but appearances at operation suggested perforation due to pressure necrosis at the site of an obstructing band. Perforation due to distension of the small gut is uncommon.

Case 18 — Perforation of the ileum secondary to strangulation

A woman of 50 was admitted to hospital complaining of a two-day history of intermittent upper abdominal pain increasing in severity. She had vomited and had had absolute constipation since the onset of the pain.

On examination. Dehydrated. Temperature 99.2. Pulse 90. Abdomen distended. Generalized guarding with maximal tenderness in the left iliac fossa. Bowel sounds normal. Rectal examination disclosed nothing abnormal.

A diagnosis of intestinal obstruction was made. The patient was prepared for laparotomy with drip and suction.

Laparotomy revealed a gangrenous loop of terminal ileum loose in the pelvis. There was a 1.25 cm. perforation at the apex of the loop but little peritoneal contamination. The loop of intestine had been strangulated in a peritoneal fossa at the base of the pelvic mesocolic attachment. The gangrenous bowel was rapidly resected and a double-barrelled ileostomy constructed, this being done in preference to an end to end anastomosis in view of the distension of the gut and the poor condition of the patient. The abdomen was closed with drainage.

The patient was treated post-operatively with drip, suction, penicillin and streptomycin and made a good recovery. The ileostomy was closed successfully three weeks later.

Comment. This was of interest in that the strangulation had reduced spontaneously, but not before the development of gangrene leading to perforation. Perforation had occurred in the most friable region of the involved loop, on the antimesenteric border.

Case 19 — Perforation proximal to obstruction due to faeces

A woman of 61 was admitted to hospital on 16th June, 1949, with an indefinite history suggesting intestinal obstruction. For the past two days she had been vomiting profusely and had passed no flatus or faeces for twenty-four hours. She had also noticed that her abdomen had become swollen.

On examination. She was pale with a rapid pulse and a dry tongue. The abdomen was grossly distended. Free fluid could be detected. No bowel sounds were present. Rectal examination revealed no abnormality.

Despite the absence of bowel sounds a diagnosis of acute large intestinal obstruction was made. Preoperatively a Ryle's tube was passed and the patient was given 500 ccs. of 5% dextrose in water and 500 ccs. of blood intravenously.

Laparotomy revealed a general peritonitis with free gas and foul smelling fluid in the peritoneal cavity. The caecum and the ascending colon were grossly distended due to the presence of impacted faeces in the sigmoid colon. Two minute perforations were present in the anterior wall of the caecum but minimal leakage had occurred. No foreign body was found to account for the perforations. It was assumed that these had resulted from the distension, no ulceration being obvious. The perforations were closed with catgut tied over an omental graft. The faecal masses were broken up manually and the abdomen was closed with two drains to the pelvis.

Post-operatively the patient was treated with drip and suction together with penicillin and soluthiazole. Morphine was given as necessary. Despite these efforts the patient went down hill and died three days after operation.

Post-mortem revealed a general peritonitis, and no other cause was found for the perforated caecum.

Comment. Faecal impaction occasionally causes large bowel perforation, either from stercoral ulceration at the site of impaction, or, as in this case, from overdistension of the caecum. The caecum is most vulnerable to perforation as it is the thinnest walled part of the large gut and in cases of obstruction, suffers the greatest intraluminal pressure. This case was a closed loop obstruction. Since the obstructing lesion was overcome at

the operation simple suture of the caecum was considered justifiable. Caecostomy might have been a worthwhile precaution.

Case 20—Perforation of ascending colon due to carcinoma of the sigmoid colon causing a closed loop obstruction

A woman of 69 was admitted to hospital with a seven-day history of intermittent upper abdominal pain, distension and vomiting.

On examination. Patient obese. General condition fair. Tongue dry. Abdomen distended with gas. Generalized tenderness and guarding.

A diagnosis of subacute intestinal obstruction was made. After preparation by drip and suction laparotomy was undertaken.

Laparotomy. The peritoneum contained free gas. The ascending colon was grossly distended due to the presence of a tight annular carcinoma obstructing the sigmoid. There was a 0.5 cm. perforation half-way up the anterior wall of the ascending colon. The perforation was closed, transverse colostomy was performed and the abdomen closed with drainage.

Post-operatively the patient was treated with drip, suction, penicillin and streptomycin and made an uncomplicated recovery.

Her neoplasm was later resected with end to end anastomosis of the colon.

Comment. This illustrates a common cause of closed loop obstruction in the large bowel and the result of its neglect. In this case the ascending colon rather than the caecum, perforated.

Case 21 — Perforation due to incompletely relieved closed loop obstruction

A man of 60 had an ileo-transverse colostomy (without division of the ileum) on 18th October, 1949, for a fixed stenosing carcinoma of the ascending colon with secondaries in the liver and peritoneum. He made an uninterrupted recovery from this operation.

On 31st December, 1949, he was admitted to hospital collapsed, with severe abdominal pain and vomiting. Despite attempts at resuscitation he died a few hours after admission.

Post-mortem revealed a rupture of the colon proximal to the carcinoma. The peritoneal cavity was full of faeces.

Comment. In this case the original operation had only partially by-passed the colonic obstruction and some of the ileal contents must still have entered the ascending colon through the ileo-caecal valve. With a competent valve at one end and a stenosing carcinoma at the other a closed loop resulted and the intraluminal pressure eventually rose to such an extent that the colon ruptured. If a by-pass operation of this type is contemplated the ileum should preferably be transacted, the distal end closed and the proximal end implanted distal to the obstruction as an end to side ileo-transverse colostomy.

6. *Neoplasm*

Perforation is occasionally the first manifestation of an intestinal neoplasm, usually in the colon or upper rectum. Such a catastrophe occurs in 2 per cent. of large bowel growths and is due to the tumour mass outgrowing its blood supply, or to spontaneous thrombosis of the tumour vessels. A large perforation results in a faecal peritonitis which carries a high mortality.

Illustrative cases

Case 22—Perforated carcinoma of the caecum

A man of 71 was admitted to hospital on 29th April, 1956, with a two months history of abdominal pain which had become severe during the past six hours. Appetite poor with no vomiting. Bowels loose, micturition normal. There was a history of recent weight loss.

On examination. General condition poor. Temperature 98.2. Pulse 80. Abdomen rigid all over with maximum tenderness in the right iliac fossa. No bowel sounds. Nothing abnormal was detected on rectal examination.

Laparotomy on 29th April, 1956, revealed a large perforated carcinoma of the caecum. There was a general peritonitis and multiple secondaries in the liver. There was no evidence that the growth was causing obstruction.

An ileo-transverse colostomy was performed and the abdomen closed with drainage.

Post-operatively the patient was treated with penicillin and streptomycin, drip and suction and made an uncomplicated recovery.

Comment. This case was operated on soon after perforation, for although there was a general peritonitis it was not offensive in nature. It is noteworthy that no faecal fistula developed.

Carcinoma of the caecum rarely causes obstruction as the bowel is capacious at this point. It is often an exuberant growth and in the above case necrosis and perforation must have resulted from inadequate blood supply.

Case 23 — Perforation of a carcinoma of the rectum

A woman of 48 was admitted to hospital on 17th July, 1948, complaining of a five-hour history of sudden abdominal pain. The pain was hypogastric and was increasing in intensity. She had vomited

and become constipated two days prior to admission. Micturition made the pain worse. During the previous three weeks she had had two attacks of pain in the left lower abdomen.

On examination. General condition good. The whole lower abdomen was tender and rigid. Bowel sounds were absent. The anterior rectal wall was tender to digital examination.

A Ryle's tube was passed, a drip set up and laparotomy undertaken. Laparotomy revealed peritonitis due to the perforation of a carcinoma in the anterior wall of the upper (intraperitoneal) rectum. There was a secondary nodule on the uterus but the liver was free from growth.

A Lahey procedure with terminal left iliac colostomy was performed. The abdomen was closed with drainage.

Post-operatively the patient made a good recovery and four weeks later the rectum, anal canal and uterus were removed by the synchronous combined technique. Microscopy showed a moderately well differentiated adenocarcinoma of the rectum.

Three years later the patient was alive and well without evidence of recurrence.

Comment. The history of vomiting and constipation together with pain in the left lower abdomen which preceded the actual perforation is characteristic and may be found in 50 per cent. of cases. It may be that constipation is the ultimate cause of perforation, for in the above case the growth was relatively small and unlikely to have outgrown its blood supply.

THE DIAGNOSIS OF INTESTINAL PERFORATIONS

The majority of these cases present as acute emergencies with general or local peritonitis which is easy to diagnose. The fact that an intestinal perforation is the cause of the symptoms is often more difficult to recognize, but is important so that specific treatment may be given and the site of laparotomy planned.

A careful history is valuable. In traumatic cases, the time and mode of injury and the posture when injured are important. In other cases the mode of onset, type and site of abdominal pain must be noted. Particular attention is also paid to recent dietary history and gastro-intestinal function.

Physical signs depend upon the extent of contamination following the perforation and this in its turn is often related to the time factor. General peritonitis is manifested by board-like abdominal rigidity and absent bowel sounds, but a localized perforation as occurs in colonic diverticulitis results in circumscribed tenderness and guarding, often with a palpable mass. Especially in the inflammatory perforations, the temperature is elevated.

Intestinal perforation following closed trauma is difficult to differentiate from a simple abdominal wall contusion. If doubt exists after four hours observation, laparotomy should be performed, for the mortality from ruptured intestine rises with each hour of delay. Note should be taken of the site and extent of abdominal bruising (if any) as this may overlie an intestinal perforation. A rising pulse rate, persisting pain, increasing abdominal rigidity and absent bowel sounds all point to the need for operative intervention. Liver dulness is diminished in cases with much free intraperitoneal gas; in other cases shifting dulness may be demonstrated. Rectal examination may reveal a tender pelvic peritoneum or blood on the examining finger.

Exploration is always necessary in open abdominal trauma even though there is no evidence of intestinal perforation. In some cases faecal drainage from the wound makes the diagnosis obvious; in others the crepitus of colonic gas may be noted at the wound site. The urine must always be examined to exclude an associated renal injury.

In the other groups, the history may give the only lead. Apart from dietary accidents, foreign bodies are likely to be swallowed in certain occupations — for example cobbling — and by mental defectives. Inflammatory perforations are often preceded by gastro-intestinal disturbance, especially diarrhoea, and obstructive perforations by intermittent lower abdominal pain.

The general appearance of the patient is sometimes suggestive especially in cases of neoplasm when cachexia and anaemia are apparent. Abdominal scars must be noted and enquired after as a possible guide to the pathology of the condition. The presence of an abdominal lump is an important finding. If it is tender it may represent a local inflammatory mass, and if non-tender and associated with distension it may be the site of an obstructing neoplasm. In neglected intestinal perforations distension and poor general condition may eliminate the board-like rigidity usually associated with general peritonitis.

The special aids to diagnosis are few. Straight X-ray of the abdomen may reveal subdiaphragmatic gas or the presence of an opaque foreign body. The fluid levels of an associated intestinal obstruction are occasionally demonstrated.

Differential diagnosis

Many of the cases presenting with general peritonitis will be diagnosed as perforated peptic ulcer or a perforated appendix. The more insidious perforations sometimes mimic, or are associated with, intestinal obstruction.

THE TREATMENT OF INTESTINAL PERFORATIONS

With few exceptions, early operation is necessary, and if the diagnosis is in doubt exploration is safer unless the condition of the patient precludes it. Occasionally a perforation localizes with abscess formation and in these cases an expectant policy is justified, the patient being confined to bed on a fluid diet; antibiotics are of limited value and eventual drainage of the abscess may be necessary.

In those cases presenting with general peritonitis, vigorous pre-operative preparation is important. The stomach is emptied through a Levin tube which is left *in situ* and fluid and electrolyte balance restored by intravenous drip. Especially in traumatic cases, blood replacement may be necessary and urgent. In such instances the use of two intravenous drips is an insurance against one of them stopping at a crucial moment. Intra-arterial drips have not been found necessary. Penicillin and streptomycin are the most generally useful antibiotics and a massive dose of each (1,000,000 units and 1.0 g. respectively) is given before operation. Small doses of morphine may be given for the control of pain during the pre-operative phase.

Operation is performed under general anaesthesia. A mid-abdominal right paramedian incision should be used unless there is definite evidence of a lesion inaccessible through such an approach. In open trauma the incision may be planned to include the abdominal wound.

Once the abdomen is opened, intra-abdominal fluid, whether it be pus or blood, is sucked or mopped away. Large collections of semi-solid blood are best removed with an abdominal pack. Obvious haemorrhage must be controlled early (Maingot, 1951) and then a systematic laparotomy can be performed with safety. Thoroughness is essential, but re-examination should be avoided.

Many small intestinal perforations can be closed transversely by suture in layers but in certain instances resection is safer and quicker. Multiple traumatic perforations, perforated Meckel's diverticulum and perforated regional ileitis fall into the latter group. If there is gross disparity in the gut lumen, end to side anastomosis is advisable.

The operative treatment of colonic perforations is controversial. If there is no obstruction and the gut is not grossly distended, small perforations can be closed in layers, preferably using non-absorbable sutures. If there is any doubt as to the safety of closure, proximal decompression or exteriorization of the perforated gut is performed. A special effort must be made to discover and close retroperitoneal colonic wounds as in these cases faecal tattooing often causes a dangerous anaerobic cellulitis of the extraperitoneal tissues (Baty, 1952).

When perforation occurs in the presence of obstruction it is as important to overcome the obstruction as to close the perforation. In the small gut the obstruction is usually due to adhesions or a hernia and the cause can be removed at the primary operation. In the large gut the obstruction is commonly due to a neoplasm and in any event the emergency operation should aim at decompressing the bowel and closing the perforation. In some cases the site of perforation will not be evident and then all will depend upon efficient diversion of the faecal stream and drainage of the abdomen. Proximal colostomy or ileo-transverse colostomy is often applicable. Occasionally, especially in the descending colon, a perforated neoplasm may be exteriorized by a Paul Mikulicz procedure and in early cases of perforated carcinoma of the caecum or ascending colon, primary hemicolectomy is occasionally feasible even in the presence of mild degrees of obstruction (Muir, 1947). In those cases of carcinoma of the large gut which perforate before causing obstruction, the methods of treatment indicated above should be applied.

If a foreign body is discovered during the course of operation, it is removed, but even when one is known to be present a prolonged and often fruitless search should be avoided.

In all cases with extensive intraperitoneal contamination the abdomen is drained using corrugated soft rubber. Drainage through the flank may be necessary in extraperitoneal large gut perforations. In cases of doubt it is safer to drain for forty-eight hours. Faecal drainage warrants retention of the tube for five days by which time a drainage track will be established.

Careful abdominal closure with interrupted sutures will ensure against the complication of burst abdomen which appears to be a real danger in these cases, possibly due to the frequency of post-operative distension and ileus.

Post-operatively, treatment is directed to the prevention of paralytic ileus. Gastric aspiration and intravenous drip therapy should be continued until bowel sounds return. Adequate and continuous sedation with morphine is valuable during the first forty-eight hours after operation. Antibiotics commenced before operation are continued until they are judged to be no longer necessary — usually three to five days. Vitamin C 500 mgm. intramuscularly daily aids healing and may protect against burst abdomen, and when faecal contamination has been severe anti-gas-gangrene serum is advisable.

SUMMARY

The causes of intestinal perforation are numerous, but all may give rise to acute abdominal emergencies requiring urgent operation. In some instances the correct diagnosis may be suggested, but more common conditions are frequently simulated.

If the abdomen is explored for a perforation whose site is not clinically obvious, a knowledge of the possible causes as detailed will be of value, and the patient will be given the best chance of survival if the routines of treatment outlined above are observed.

As to prognosis, out of 23 cases quoted, 7 died— a mortality rate of about 30 per cent. This rate will vary with the type of case but may be taken as a guide to the chances of survival.

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MICRODISSECTION OF KIDNEY FROM A CASE OF SEVERE BURNS

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ANY one method of investigation of the structure of tissues has its limitations. This is especially true of simple histological study in the case of a complex structure such as the kidney; furthermore the complexities of normal structure are exaggerated by the variety of changes which may take place in abnormal conditions. This has been well exemplified by the confusion that has occurred particularly in the last two decades in regard to hypotheses developed around the renal conditions which arise as a result of various "toxic" and vascular disturbances following crushing (muscle) injuries, surgical shock, burns, transfusion accidents and some forms of chemical poisoning (mercuric chloride, sulphonamides, di-ethylene glycol, carbon tetrachloride amongst others).

As a result of clinical and simple histological enquiry, various groups of presumed states have been described and have been given various names but most of the conditions have come within "the meaningless embrace of that most tolerant of terms, 'nephrosis'" (Oliver, MacDowell and Tracy, 1951). One of the best publicized of the terms has been the "lower nephron nephrosis."

Apart from any opinions that may be held regarding these conditions, it has been generally appreciated that insufficient information has been available. For some considerable time now, study has been made of the minute structure of the kidney by microdissection. This enables the nephron to be seen in its entirety and ensures that the various parts are appropriately orientated and thus cannot be confused with each other. This has been a most rewarding mode of approach providing information on the forms of the renal unit — the nephron — which is quite inaccessible in ordinary histological sections and most difficult to obtain by tissue reconstruction.

An opportunity for the study of the changes found in patients suffering from severe burns presented itself and the results of observations are given here. The original cases and their histological features have been recorded by Hueston, Hossack and Taft (1957). The case, the details of which are presented here, is Case 2 of the series described by them.

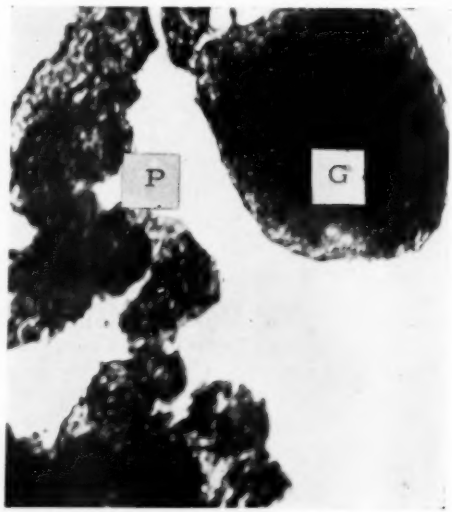

FIG. I. Photomicrograph of one of the few normal nephrons showing the glomerulus (G) with the fine translucent capsule and a small capsular space surrounding the dark central glomerular tuft. The proximal tubule (P) shows the fine stippled pattern, the complex convolution and the well-defined basement membrane of the normal nephron. (x 200)

Method

Oliver's (1939) method of preparation of tissue in concentrated hydrochloric acid was used. Small pieces of formalin-fixed tissue were taken: maceration was carried out for forty-eight hours and dissection performed by needles held manually under a binocular dissecting microscope. Photographs were taken of the unstained specimens immediately following dissection, using a Leica 35 mm. camera and Pan F film.

RESULTS

Most nephrons dissected showed gross abnormalities, often extending from the glomeruli and involving the entire proximal tubule. About one nephron in ten was not abnormal and the glomerulus could be seen as a round structure with the capsule showing as a clear narrow space about the tuft (Fig. I). Normal tubules showed a fine stippled pattern in the unstained state and the basement membrane was well formed and easily seen. Most glomeruli showed some degree of abnormality, the normal translucency being obscured by dense homogenous material and there was no evidence of remaining capsular space. The details of capsular and tuft structure were no longer visible (Figs. II and III).

The site of the break in the basement membrane occurred occasionally in an otherwise normal length of tubule (Fig. IV). Most proximal tubules showed abnormality of the cell pattern by a variation in the density of normal stippling. In the most profound examples of changes of this nature, the stippled pattern was practically obliterated (Figs. VI and VII). The loops of Henle and distal and collecting tubules, in most instances, showed normal cell patterns.

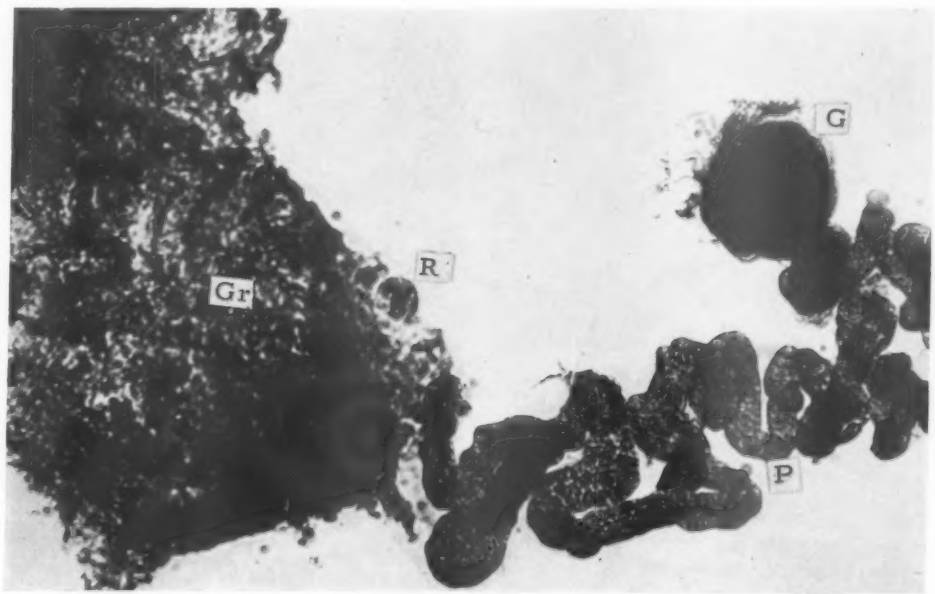

FIG. II. Photomicrograph of the commonly observed nephron. The glomerulus (G) appears darker than usual and the capsular space is almost obliterated. The proximal tubule (P) shows increased stippling and ends in an amorphous mass (Gr). A remnant of the tubule (R) can be seen within the mass. (x 90)

Tubular damage was maximal in the proximal tubule, more especially in its lower third (Figs. VI and VII). The site of most severe damage was where nephron continuity was disturbed, the basement membrane destroyed and exudate was to be seen surrounding the site of severe disruption (Figs. IV and V). The discontinuity of the proximal tubules was observed to occur in a random fashion, anywhere along the length of the proximal tubule and occasionally even in the distal tubule.

Changes in these were due to dark material within the lumens of the tubules. The cellular débris occasionally distended the tubules, but destruction of the basement membrane was never seen at the site of intratubular accumulation and deposition (Figs. VI, VII and IX).

Diverticula, often filled with débris, were seen along the length of the distal tubules (Fig. VII). Cell masses, varying in size from about 20μ diameter to 87μ (Fig. VIII) were seen attached loosely to the basement membrane of the distal tubule. They could be lifted off easily with the dissecting needles and were not continuous with the tubule cells or lumen as were the diverticula.

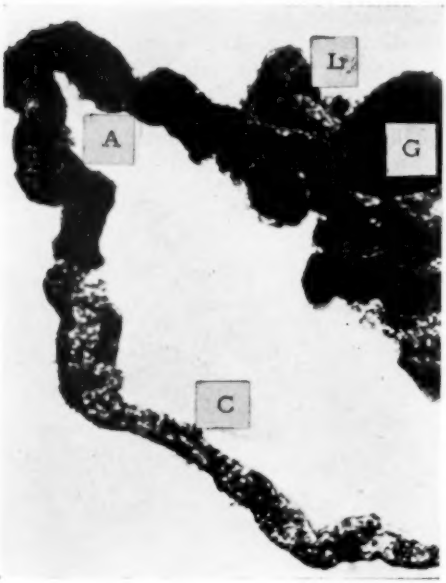

FIG. III. Photomicrograph of a nephron in which the glomerulus (G) is very dark and no capsular space is seen. A few loops of proximal tubule with a stippled pattern (L), only a little denser than normal, leads into a dilated proximal tubule (A) in which there is loss of convolutions, complete obliteration of the cell pattern, but in which the basement membrane is still intact. The tubule then continues (C) showing only mild damage. This demonstrates the patchy nature of the lesions along the length of the tubule. (x 90)

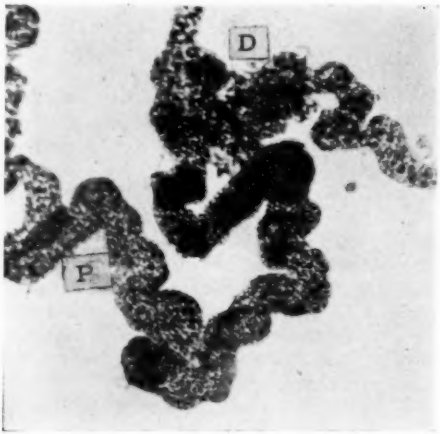

FIG. IV. Photomicrograph of the lower end of a normal piece of proximal convoluted tubule showing an isolated patch of ischaemic disruption at point (D) where there is loss of basement membrane. The tubule continues from this point with a normal stippled pattern. (x 90)

FIG. V. Photomicrograph of the lower half of a proximal tubule with some toxic changes in the cells. At the lower end just prior to the formation of Henle's loop the basement membrane is lost and the tubule is surrounded by amorphous material (Gr). Disruption is much more extensive than in the preceding illustration. (x 90)

DISCUSSION

The study of the nephrons by the microdissection technique showed that, although some of the units were normal in form and structure, a considerable number was changed in various ways. These alterations were different in different nephrons and combinations of the changes made the appearances remarkably protean and, in some cases, complex.

These changes could be divided into two main groups: that in which the changes were diffuse through part of the nephron and that in which they were more sharply localized. The former comprised changes principally in the epithelial cells of the tubules with loss of their characteristic structure — recognized as a loss of the normal "stippling." Associated with this there was an accumulation of cellular débris (and sometimes pigment) in

the lumen. These collections did not correspond to the well-defined casts of the collecting tubules but, together with the changed appearance of the lining cells, gave them a uniform opaque character which was distinctive.

FIG. VI. A loop of Henle filled with a cast which is distending the lumen. There is no loss of continuity as the basement membrane is intact. (x 90)

FIG. VII. Three distal tubules filled and distended by cast but with excellent cell definition and intact basement membrane. Diverticula (Di) were seen commonly along distal tubules. (x 120)

These changes were observed in various parts of the nephron but, from the point of view of some current hypotheses (particularly that relating to the "lower nephron nephrosis"), it is important that they occurred in the proximal convoluted tubule as well as elsewhere. The intratubular aggregations could be sufficiently large to distend the tubule and this also provided a characteristic morphological picture.

FIG. VIII. Photomicrograph of the junction of two distal tubules to form a collecting tubule. A discrete cellular mass (M) was found at this point. There was no anatomical continuity with the tubules as the mass was quite easily separated with the dissecting needles. Several small discrete masses were seen along the length of the distal tubules. Diameter of mass, 87μ. (x 200)

The localized lesions were limited to short lengths of part of the tubule or even to distinctly isolated points though, occasionally, larger segments are affected. The significant feature was the involvement of the whole thickness of the tubule wall. Associated with this there was a mass of tissue, inextricably bound to the tubule, in which this structure became lost.

The interpretation which has been placed on these two lesions is that the former is due to damage of the lining cells presumably by materials carried in the blood stream. Thus the phenomenon is called a "toxic" change.

There is clear evidence for this view in the many cases in which chemical poisoning is the initiating factor. Though the agent is less obvious in other cases such as crush injuries, the similarity of this lesion in such cases to those seen in the former makes this view probable.

FIG. IX. Photomicrograph of a nephron which shows a glomerulus and part of a proximal tubule illustrating severe toxic changes in the cells but in which the basement membrane is quite intact. There is no loss of continuity of the nephron. (x 200).

The second type of change is interpreted as a vascular lesion. Its acceptance demands an appreciation of a complexity of renal vascular supply, greater than and different from that normally described, but when this is accepted (and close study of the details of the renal circulation compels this) the difficulties are resolved. The reasons for this vascular interpretation are the extreme patchiness of the lesions and the necrosis of the tubular wall due to loss and disruption of the basement membrane as well as the cells. It has been designated by Oliver *et alii* (1951) as "tubulorhextic."

Though these two types of lesions appear to be fundamentally dissimilar, and therefore it might be argued that their association in the one organ must be fortuitous, it is significant that they are found in all cases of renal damage due to cellular poisoning.

The former type of change is more prominent in the case recorded here than in many cases of "acute renal failure," and both glomeruli and tubules are involved. The appearances corresponded closely with and, indeed, mimicked those observed histologically in uncomplicated cases of phosphorus poisoning (McLean *et alii*, 1929; Diaz-Rivera *et alii*, 1950; Perry, 1953); they were notable and conspicuous features of this tissue and it is probable that primary toxic effects of phosphorus poisoning are, in this case, added to other changes.

This cellular damage, though predominating here, is not necessarily confined to the epithelium of the kidney and as a result of injury to other organs (particularly those of the vascular system) circulatory changes are almost invariable. In other cases where vascular disturbances play a more direct role in development of a condition there is some diffuse damage of parenchyma as well as the localized lesions due to gross local ischaemias.

It is apparent that in all these cases of acute renal failure there is a close, and probably invariable, association of the two factors, cytotoxic damage (whether chemical or due to poor vascularity) and localized gross deprivation of blood supply (of the nature of infarcts of arteriolar distribution) giving rise to the two lesions which are described as "toxic" and "ischaemic." The association of these two, thus, is not fortuitous but rather is an inevitable partnership due to the close inter-relation of the aetiological factors.

In the case of the burns, the lesions observed are comparable with those seen in other types of renal failure and, from the information obtained in these other cases, a complex and, at first sight, apparently inextricable conglomeration of changes can be both literally as well as figuratively disentangled.

This elucidation has become possible through the microdissection technique principally as the result of the pioneer work of Oliver and his colleagues. That his brilliant contributions have not yet universally received the attention they deserve is the reason for the presentation of the results of this present study in some detail.

SUMMARY

A kidney, the site of an "acute renal failure" following burns, was investigated by the microdissection technique.

Most of the nephrons showed significant changes and these were of diverse characters. They comprised changes of the tubular epithelium which are regarded as "toxic" in character and other localized lesions which show necrosis of the whole of the tubular wall, considered to be due to vascular failure, that is, they are part of arteriolar infarcts.

These lesions, though of different aetiology, are commonly associated in various forms of poisoning, surgical shock, muscle injuries and other conditions giving renal failure.

In this case the burns were due to phosphorus and some of the features, particularly a predominance of glomerular and tubular toxic change, appear to have been due to the action of this poison.

This method of study (by microdissection), because of the complexity of renal structure and intermingling of the renal units (as well as the jumble of pathological states affecting these), is of special value in the elucidation of such renal conditions.

ACKNOWLEDGEMENTS

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TREATMENT OF MEGAURETERS BY MULTIPLE MICTURITION

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HAVING previously introduced multiple micturition as a form of active therapy for certain types of megaureter (Stephens, 1954), I wish here to indicate which type of megaureter is amenable to a particular treatment; to discuss the various modifications of multiple micturition now in use — double, triple or multi-micturition; and to review the clinical state of those children who have been under treatment by members of the Urinary Clinic in this hospital.

Types of megaureter

There are two main types of congenital megaureter:

(1) An idiopathic megaureter with relaxed uretero-vesical sphincteric junction and reflux of the vesical urine into a dilated ureter.

(2) A megaureter with obstructed uretero-vesical sphincteric junction of which prolonged emptying time is the feature and with which reflux is not associated. Here again the cause may be idiopathic or it may be obvious, for example a stricture.

In the first type the reflux megaureter is of interest to the paediatrician mainly because of the disarrangement of the function of the uretero-vesical "lock" mechanism, a delicate mechanism, which normally neither obstructs the flow of urine, nor allows its reflux, but which is abnormally relaxed, the characteristic of this type of megaureter. This faulty mechanism allows reflux of urine from the bladder into the ureter.

The second, the obstructive type, is the opposite derangement of function in the uretero-vesical "lock" mechanism, and this is referable to different underlying pathology.

Both conditions, however, lead to a prolonged retention of urine — in effect to a stagnation — which unless promptly recognized and treated, leads to a urinary infection and ultimately disintegration of the renal system on one or both sides.

Idiopathic Megaureter with Vesico-ureteral Reflux

Megaureter with reflux is usually a bilateral anomaly, but it may affect one side only. It also occurs frequently in one or both ureters of a double ureter which malformation may be unilateral or bilateral (Stephens, 1956).

From a study of specimens of horseshoe kidney we have learnt that vesico-ureteral reflux is also common in the dilated ureters of this condition.

Although megaureter with reflux is a serious condition and a severe affliction of childhood, it is fortunate that this anomaly and the condition to which it gives rise, lends itself, if discovered early, to the simple forms of treatment described in this paper, namely, multiple micturition therapy. This treatment has proved not only curative, but also of considerable preventive value.

To achieve its full value, early diagnosis, intense and prolonged practice of multiple micturition therapy and a simple but long after treatment are called for. And also the patient must be made aware of the fact that this prophylactic micturitional therapy is necessary for a period of years and possibly for life.

The conclusion reached after much study of this clinical problem is that the etiology of reflux megaureter is a major study and one bristling with problems.

In particular, two observations which we have made on children with double ureters have a bearing on this statement. They suggest to us that the uretero-vesical valve mechanism — the "lock" mechanism, is an intrinsic part of the ureter, not of the bladder, and that it is an active mechanism, not a passive flap valve.

In the first observation we found with double ureters that when the orthotopic and ectopic ureters entered the bladder through the same intramural tunnel, one ureter may

permit reflux and the other may not. But in the second, the ectopic ureter with a longer than normal submucous course in the bladder may fail to prevent reflux.

These and other observations lead us to draw several conclusions and to offer some hypotheses, all of which have a valuable bearing on the treatment of megaureter by multiple micturition. They are enumerated as follows:

That the largeness of the calibre of the reflux type of megaureter is a pre-determined anomaly, that is, it is non-progressive and is unrelated to the reflux;

That the reflux is related to a faulty uretero-vesical mechanism which is an additional defect;

That the reflux of urine into the ureter is harmless in the absence of infection;

That multiple micturition is the treatment of choice, but is successful only if the patient faithfully follows the prescribed regime of treatment, and both physician and patient attain an awareness of the danger of return of infection if multiple micturition is not maintained on a preventive basis.

For success in multiple micturition therapy there is much importance attached to early accurate diagnosis. The history of the patient may be of short or even lifelong duration. The disorder may cover a considerable period of time; it may be chronic, or recurrent, with crises of pyelonephritis, pyuria, rigors and pains in the loin. This is a complex which may alternate with otherwise symptomless attacks.

It is necessary to establish by clinical and radiographic tests the calibre of the ureter, or ureters; to determine the presence of reflux, the ureteral emptying times and the renal function. All are relevant.

Double micturition is a routine measure in the elucidation of the problem of infection in the urinary tract. This test is positive if the child can pass a second specimen of urine two minutes after the first emptying of the bladder. Where does the second specimen of urine come from? Micturition cystourethrography will give the answer. The iodide may be retained in the ureters by reflux from the bladder. If so, reflux, affecting one or more of the ureters becomes apparent —and the cause of the positive double micturition test is clear.

Simple repetitive micturition is the treatment of election. Radiographically it can be shown that in nearly all patients, triple micturition can completely clear out all stagnated urine which has been allowed by the enfeebled sphincteric mechanism to pool in the dilated ureter. Triple micturition is an effective guard against urinary infection in cases of vesico-ureteral reflux.

MEGAURETER WITH OBSTRUCTED URETERO-VESICAL SPHINCTERIC JUNCTION

Less frequently we see an obstructive form of uretero-vesical megaureter. Here there is no leak of vesical urine as a urinary reflux. In this instance stagnation occurs by delayed emptying. The cause of this is not always clear. From our observations we believe that the condition is developmental in origin. The obstructing mechanism may be either an idiopathic functional imbalance of uretero-vesical sphincteric mechanism, or an unequivocal organic obstruction of the ureteric orifice, with or without ureterocoele formation.

These obstructive types of megaureter do not lend themselves to micturitional treatment in the manner applicable to the flaccid sphincter type. The obstruction requires surgical ablation. As this operation quite often begets vesico-ureteral reflux, stagnation of urine and infection ensue. In this event multiple micturitional treatment is called for in order to cure the pyo-ureter acquired from the operation. This is in contrast with the congenital megaureter with relaxed uretero-vesical sphincter, in which reflux is an integral part of the disease complex.

If acquired post-operational infected reflux were not treated with multiple micturition, chronic pyuria would persist, ultimately to destroy the kidney. Here micturitional treatment is used in a secondary capacity and its use in this manner is not strictly comparable with that for infections of the congenital relaxed sphincteric megaureter.

In this group of children the congenital obstruction to urine outflow occurs at the uretero-vesical junction. The young patients suffer a subdued type of ureteral colic, the

pains being mild, vague in their distribution, and associated with impairment of general health; sometimes there is intermittent haematuria or infection — all these make the characteristic clinical picture. Later in the history of the disease there may appear in the ureter or renal pelvis calculi which are secondary to the chronic obstruction, and which are found usually lying free in the lumen. These calculi are usually "silent" non-obstructing additions to this clinical picture. Routine urinary investigation shows delay in the emptying of the megaureter. In these patients the double micturition test is "negative" and the micturition cysto-urethrogram shows no reflux.

MULTIPLE MICTURITION

By the act of micturition in the normal infant the bladder is completely emptied and remains empty for the next few minutes. The child is physically unable to pass a second quantity of urine within two minutes. If, therefore, a second specimen of urine is obtainable in two minutes, an abnormality in the urinary tract should be suspected.

This is now known as the double micturition test. When positive, this test indicates that some urine is retained after micturition either as vesico-ureteral reflux, as a reflux into a vesical diverticulum, or as a result of urethral obstruction. Micturition cysto-urethrography will confirm the location of the residual urine.

Multiple micturition can be used for management of megaureters in two ways:

(1) Triple micturition for Type I congenital megaureter with vesico-ureteral reflux. We have been able, by radiographic means, to establish the fact that reflux in this group of cases can be effectively and totally removed by a series of three acts of micturition carried out precisely at two-minute intervals. This is confirmed by the rapid clinical improvement of patients who have carried out triple micturition for this type of megaureter deformity. If the calibre of the ureter is not much enlarged "double" micturition may suffice to empty the urinary tract.

Triple micturition will also prevent re-infection in the urinary tract in these patients with congenital megaureter with reflux.

In this way many operations can be averted and many kidneys can be saved, and we have avoided heminephrectomy operations in a number of our double ureter patients. We suggest that the megaureters in some people with horseshoe kidneys may now be shown to be of the reflux type, in which event they are more amenable to triple micturition than to surgical correction of the deformity.

(2) Multi-micturition for Type II congenital obstructive megaureters. Micturition cysto-urethrography performed on patients subsequent to operative procedures which have successfully eliminated uretero-vesical obstructions has demonstrated vesico-ureteral reflux of urine. This pooling of urine accounts for the heavy urinary infections which so often follow these operations. By extending the radiographic investigations we have been able to show the existence of the reflux and the effectiveness of multiple micturition — sometimes as many as 8 to 10 or more repeats at two-minute intervals — will climinate most of the residual pool of urine from the urinary tract. For descriptive purposes, this form of multiple micturition is called multi-micturition.

After a period of several months of faithful practice of multi-micturition, aided by antibiotics, the urine becomes clear.

Multi-micturition has now been used successfully for this "acquired" reflux which has followed operations such as vesico-ureteral meatoplasty and ureteroneocystostomy for idiopathic obstructive megaureters, ureteroplasty for ureterocoeles, and diverticulectomy for the para-ureteral diverticulae.

Operative interference with the uretero-vesical valve mechanism in some way adversely affects the efficiency of multiple micturition therapy. More than three repeats of micturition become necessary, more practice is needed by the patient, and even then some residual urine may remain. Nevertheless, multi-micturition is an essential factor in the successful management of this type of infection.

Frequency of multiple micturition

"Multiple micturition" is indicated for patients with vesico-ureteral reflux both for cure in the phase of active urinary infection, and for prevention of recurrence of infection.

In the phase of active infection together with antibiotic treatment, multiple micturition should be practised at least three times in the day. Once the infection has been overcome and the urine is clear and sterile, multiple micturition is required only once daily. The patient and parents should be made thoroughly aware of the fact that this is a life-long duty; that failure to carry out this treatment will result in reinfection, and that reinfections relentlessly destroy the kidney.

It is noteworthy that some children quickly master the act of multiple micturition but others take longer and patience on the part of parent and physician is required. Others again become tired of the procedure and require stern warnings by their physician whose orders they are more likely to heed.

RESULTS OF MULTIPLE MICTURITION TREATMENT

Megaureters with reflux

Thirty-three children have been maintained in good health on daily prophylactic triple micturition therapy. The vesico-ureteral reflux affected both ureters in 22, the left ureter in 9 and the right in 2. They have been followed now for periods ranging between three months and six years. They have maintained good health during these periods with only a rare instance of infection. In all, the urine is now pus free and sterile.

One additional child, dwarfed by hypoplastic kidneys which were further damaged by prolonged chronic pyelonephritis, became pus free for two years after beginning triple micturition therapy but ultimately died of uraemia.

A further 20 children, having unilateral or bilateral double ureters, one, two, three, or all four of which permit vesico-ureteral reflux, are practising prophylactic multiple micturitional therapy. Ten of these children perform triple micturition as adequate for their anomaly. The remaining 10 require to carry out multi-micturition. These 10 children require post-operative multiple micturition treatment not only for the reflux residual urine which has supervened in the ureter as a result of surgery, but also in most instances for one or more of the other reflux ureters, the uretero-vesical mechanisms of which are congenitally debilitated. All the children are in good health and their urine is pus free and sterile. The remainder of the children in the series of double ureters, now totalling 46, either need no treatment, have been cured by radical operative procedures, or have died in infancy (2 cases). These children have been under observation for periods even as long as six years, during which only occasional instances of reinfection have been recorded. Reinfection is more likely in those children whose obstructive ureters have been converted by operation into the acquired reflux group. But over all, the health, progress, and urinary condition of these patients have been very satisfactory.

Megaureters with obstruction

Eight children with idiopathic obstructive megaureters (6 bilateral and 2 unilateral) were subjected to operations on the ureterovesical junction and have now been followed for periods ranging from six months to three and a half years. In all these ureters the obstruction was overcome but free reflux occurred subsequent to operation. The operation on thirteen of these ureters was a sutured vesico-ureteral meatoplasty and in the fourteenth, the ureter was transplanted into the bladder. Multi-micturition several times daily was necessary for up to six months before the urine became free of pus. During this period of infection the treatment was combined with antibiotics which were administered according to the changing sensitivities of the organisms. In 7 of these children the urine gradually improved, being at first thick and smelly, but finally crystal clear. They now successfully practice prophylactic multi-micturition. In one other, whose operation was the most recent, and who is now afebrile and healthy, the urine is not yet sterile.

CONTRA-INDICATIONS TO USE OF MULTIPLE MICTURITION IN MEGAURETERS

Triple micturition is not a panacea for infections resulting from all forms of residual urine. To preserve it for the anomalies for which it is so clearly indicated is to maintain its high reputation as a simple remedy in those conditions. Those forms of residual urine for which multiple micturition therapy is inapplicable are set out below:

1. We have been unable to remove, by multiple micturition, all the residual

urine retained in an enlarged megaureter complicated by a large paraureteral diverticulum. This association of diverticulum and megaureter is a well-recognized combination in children. But after diverticulectomy multiple micturition is effective.

2. Micturitional therapy has little value in the case of unilateral giant megaureter with reflux. Apart from the fact that the renal function in the corresponding hypoplastic kidney is usually poor, repetitive micturition may only incompletely remove the residual content, and the pyuria persists.
3. Micturitional therapy is obviously inapplicable in the reflux megaureter associated with the paretic bladder of lumbar meningomyelocoeles. Though this megaureter behaves in a similar way to the previously described reflux type, the paralytic bladder is unable to expel the urine by voluntary effort — even triple Crédé expression is inefficient and unlikely to remove the residual urine and the concomitant chronic urinary infection.
4. Residual urine caused by urethral obstruction which can be clearly detected on the cysto-urethrogram, cannot be removed by repetitive micturition. Treatment must obviously be directed to removal of the cause of the urethral obstruction rather than removal of the residual urine.
5. Finally, triple micturition is obviously inapplicable in babies under 18 months. Resort to antibiotics is indicated; but perhaps in a very few selected cases operation to provide free drainage is required, as a temporary measure, in this age group.

CONCLUSIONS

Multiple micturition techniques are applicable in both clinical and radiological diagnosis and in the treatment of megaureters.

The double micturition test, a test which indicates the presence of residual urine, is used clinically for children whose symptoms are related to pyuria. When the test is positive, megaureter with reflux is suspected.

Confirmation of the presence of residual urine and its location is obtained by micturition cysto-urethrography which can be extended to show whether two, three, or more repeats of micturition are required to empty out this residual content.

Multiple micturition is the term applied to these repetitive acts of micturition at two-minute intervals. This repetition empties the urinary tract of all residual urine and so both cures and prevents urinary tract infection in congenital megaureter with vesico-ureteral reflux. Triple micturition is adequate for this group of reflux megaureters but multi-micturition which involves more repeats of micturition is necessary for the surgically acquired reflux of the obstructive megaureters.

Sixty-one children under treatment by multiple micturition therapy have remained free of infection except for rare instances of short-lived recurrence, the cause of which was usually traced to neglect of the prescribed routine.

Multiple micturition techniques are indicated chiefly for the infections associated with the reflux pooling of urine in the ureters caused by congenital or surgically acquired debilitation of the uretero-vesical valve mechanism. Because of the patients' physical inability to eliminate by repetitive micturition the residual urine caused by other more complex congenital anomalies enumerated in this paper, these techniques cannot be used indiscriminately.

ACKNOWLEDGEMENTS

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STEROID ANAESTHESIA

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In 1941 Seyle showed that, in animals, certain of the adreno-cortical steroids possessed anaesthetic properties. He also pointed out that one such steroid, pregnanedione, whole possessing anaesthetic potency, had no hormonal activity. Laubach, P'an and Rudil made a study of the anaesthetic properties of various steroids with a view to finding one suitable as an anaesthetic agent. From animal studies, they suggested that 21 hydroxy pregnanedione sodium succinate could prove to be a satisfactory anaesthetic agent (Laubach *et alii*, 1955).

This substance was prepared by Pfizer under the trade name of Viadril and early clinical trials were reported by Murphy *et alii* (1955). Since that date there have been numerous clinical reports on the anaesthetic properties of the drug.

Over the past two years I have been fortunate in having the opportunity of giving this agent clinical trial. During this period I have administered the drug in conjunction with Dr. W. H. J. Cole to 212 cases and it is proposed to give a brief description of our experience.

Properties of Viadril

Viadril is a white powder, water soluble but unstable in solution. It is a soap and tends to froth when dissolved thus making the preparation of the solution rather tedious.

It is employed as an intravenous anaesthetic in a strength of 0.1 per cent. More concentrated solutions are strongly alkaline with a pH of 8.5-9.8 and cause intense irritation of the veins.

The potency of Viadril is, milligram for milligram, one-quarter that of thiopentone but the therapeutic index is five times that of thiopentone. Therefore, there is greater margin of safety. The agent is reported to have no hormonal activity and little effect on metabolism or on serum electrolytes nor does it cause haemolysis (Laubach *et alii*, 1955).

If 500-1,000 mgms. of the drug are slowly injected intravenously, the patient will fall asleep after an interval of five to ten minutes. It is suggested (Gordon *et alii*, 1956) that this delay in action may be due to the fact that Viadril is changed by the liver into the ultimate agent which produces the anaesthetic effect. The exact mode of action of Viadril on the cerebral cortex is not known but it is thought to be an interference with dehydrogenase mechanisms in cell metabolism (Seyle, 1942). The pattern of the E.E.G. under steroid narcosis is similar to that produced by thiopentone (Boyen *et alii*, 1956). The excretion of Viadril is uncertain but thought to be via the kidneys in a conjugated form, possibly as a glycuronate.

Clinical Use

Viadril may be employed in two different ways:

(i) As a basal anaesthetic agent

With this method Viadril in doses of 500-1,500 mgms. is given by slow intravenous injection as a single dose. Because of the irritant nature of the solution, it must be injected into a large vein and in a 0.1-0.2 per cent. solution; this involves the administration of a large quantity of fluid and is a time-consuming procedure.

After a delay of five to seven minutes the patient falls asleep and, although unrouseable, may respond violently to painful stimuli, indicating that Viadril has little analgesic effect. Respiration is usually normal or only slightly depressed. Slight hypotension is common but occasionally a severe drop in blood pressure is encountered. The duration of hypnotic effect of a single dose is between forty to one hundred minutes.

Supplementary analgesia is necessary for surgical procedures and any inhalation agent can be employed, nitrous oxide being the common supplement. In addition, for longer procedures, pethidine or omnopon and further doses of Viadril may be necessary. Relaxation is variable but, in general, is poor. It

is possible to insert an oropharyngeal airway but endotracheal intubation can not be effected without a relaxant.

Used this way, Viadril makes a pleasant basal anaesthetic but has few, if any, advantages over any other basal anaesthetic agent such as bromethal or rectal thiopentone.

Viadril by this technique was employed in 10 neurosurgical operations and was found to have little to recommend it — the dose was difficult to judge, the effect variable, for a prolonged case further Viadril was necessary and the delay of action after injection made control difficult.

(ii) By continuous intravenous drip

This technique has been employed in all but 10 of our series of cases.

Pre-medication is usually with omnopon and scopolamine, omnopon or pethidine and atropine, and, in the neurosurgical cases, atropine only. Induction of anaesthesia is with minimal thiopentone, a relaxant is given for intubation, the larynx and trachea are sprayed with local analgesic solution, and an endotracheal tube is passed.

As soon as adequate spontaneous respiration is present, Viadril is administered by continuous intravenous injection. A 0.01 per cent. solution is employed in all cases except in neurosurgical patients where a 0.2 per cent. solution is used to avoid excessive administration of fluids. The Viadril is administered rapidly at first until slight respiratory depression is noted when the drip is slowed to a maintenance level. Rate of administration is regulated according to depth of respiration and level of blood pressure. A rise in blood pressure, expiratory contraction of the abdominal muscles, tachypnoea, or movements of the limbs usually mean that the patient is too light. The patient's sensitivity to Viadril can be gauged from the dose of thiopentone required for induction.

The average dose of drug varies according to the size of the patient, age, duration of operation and pre-medication but is usually between 400 and 1,600 mgms. The longest operation undertaken with Viadril was of six and a half hours duration.

With this technique analgesia is usually obtained with nitrous oxide/oxygen and only in rare instances is any other supplement required.

The recovery from the anaesthetic usually takes ten to twenty minutes and emergence is pleasant with a minimum of post-operative nausea and vomiting. Frequently, there is a short bout of shivering. Patients are often euphoric and spontaneously commend the anaesthetic.

Our cases employing Viadril total 212 and can be tabulated as in Table 1.

TABLE 1

Type of Case	*Number*
Fenestration	25
Mastoidectomy	20
Neurosurgical procedures:	
Intradural	61
Extradural	37
Laminectomy	24
Thyroidectomy	10
Herniotomy	8
Orthopaedic procedures	15
Dissection glands of neck	8
Dissection glands of groin	2
Skin grafts	2
Total:	212

Viadril was found to be most successful in the surgery of the head and neck and in prolonged cases requiring little or no relaxation. The technique was not successful for short operations as the anaesthetic was only just settled when the operation was completed, and patients tended to sleep too long.

COMPLICATIONS OF VIADRIL

(i) Hypotension

Mild hypotension occurs frequently, the systolic blood pressure usually being between 100 and 110 mm. of mercury. This fall is not regarded as significant. Occasionally a severe fall in blood pressure may occur — in this series, only when the Viadril has been given in the single large dose technique or where there has been a massive haemorrhage. Even where there is a considerable drop in blood pressure, the patient is warm and pink

and has the appearance of one who has received ganglionic blocking agents. The fall in blood pressure can readily be reversed by posture and vasopressors.

TABLE 2

Complications of Viadril	*No. of Cases*
Hypotension:	
Moderate (80-100 mm of mercury)	9
Severe (below 80 mm. of mercury)	4
Respiratory depression:	
Slight	19
Severe (apnoea for ten minutes)	3
Thrombophlebitis:	
Mild	29
Severe	5

(ii) Respiratory depression

Depression of respiration will definitely appear if an excessive amount of Viadril is administered over a short period. In one case respiratory arrest occurred for ten minutes. Respiratory depression is not a complication when the rate of dosage is carefully regulated but is a useful indication of overdosage. Respiration is readily controlled when a patient is receiving Viadril, even though there is no depression.

(iii) Thrombophlebitis and venous thrombosis

Venous reaction is by far the most common complication with Viadril. It occurred in a mild form in 29 of our cases and in a severe form in five. The severe cases followed prolonged administration for longer than 3 hours of 0.2 per cent Viadril and definite thrombosis was present. In all the mild cases a 0.2 per cent. solution was employed for periods varying from 1-3 hours. It has not occurred in any case where 0.1 per cent. concentration has been employed.

In prolonged neurosurgical cases where it is desirable to employ the more concentrated solution I have recently used only large veins, changed the vein after two hours and injected a few ccs. procaine and hyaluronidase round the vein at the end of the operation. In these recent cases, there have been no instances of venous irritation.

ADVANTAGES OF VIADRIL

(i) Spontaneous respiration is possible for prolonged periods. In a patient receiving Viadril, respiration is even, quiet and natural, although an endotracheal tube is present. There is no tracheal tug or expiratory wheeze, frequently seen when intermittent thiopentone, pethidine or trilene is used.

Viadril has the useful property of depressing pharyngeal, laryngeal and bronchial reflexes without associated depression of respiration. However, severe laryngospasm and bronchospasm can occur if an attempt is made to perform endotracheal intubation under Viadril alone.

(ii) Using the technique with nitrous oxide as described above, there is no explosion hazard.

(iii) There is little or no effect on blood pressure or pulse rate.

(iv) Unlike other anaesthetic agents such as trichlorethylene, cyclopropane and fluothane, Viadril does not cause any sensitization of the heart and therefore can be used in association with adrenaline.

(v) Post-operative recovery is rapid, there is a minimum of shock or metabolic change and nausea and vomiting are rare.

DISADVANTAGES OF VIADRIL

(i) Delay in onset of hypnotic effect.

(ii) Minimal analgesic action.

(iii) Viadril produces little or no muscle relaxation.

(iv) Technique of administration by continuous intravenous drip is rather cumbersome.

(v) High incidence of venous irritation.

CONCLUSIONS

In the search for the ideal anaesthetic agent the following requirements would need to be fulfilled:

(i) Low toxicity and high therapeutic effect.

(ii) Minimum side effects on the vital centres, the heart, liver, kidneys and adrenals.

(iii) It must be hypnotic, analgesic and produce muscle relaxation.

(iv) Compatibility with other drugs, e.g. procaine, muscle relaxants, hypotensive agents and adrenaline.

(v) Ease of administration, ready control and rapid elimination.

(vi) It must be non-explosive.

(vii) Minimal post-operative effects.

Considering Viadril from this aspect, it falls far short from the ideal. It is not analgesic, does not produce adequate muscle relaxation and is not particularly simple to administer.

On the other hand, Viadril gives little cause for anxiety as it possesses low toxicity, has a minimum effect on vital functions, is compatible with most drugs, is non-explosive, and the patient reaction after operation is good. No anaesthetic agent produced to date possesses all the properties listed above, and, in these days of balanced anaesthesia, it does not seem necessary that we should postulate any one ideal anaesthetic as different techniques should be employed in different circumstances.

Many anaesthetists and surgeons believe that spontaneous respiration is an advantage under certain circumstances and that it is not justifiable to administer muscle relaxants in doses sufficient to produce respiratory paralysis, merely to permit a patient to tolerate an endotracheal tube. The use of Viadril permits of an even, light plane of anaesthesia with spontaneous respiration and minimal complications during and after operation.

In our experience, Viadril used in the technique described would appear to be the best agent at present available for prolonged operations, especially of head and neck, where raised venous pressure is undesirable, little muscular relaxation is required, adrenaline is used and where there is an explosion hazard.

At present there is little likelihood that Viadril will replace thiopentone. However, it is possible that Viadril is only the introduction to an era of steroid anaesthetic agents. When the chemists can produce a non-irritant intravenous steroid anaesthetic with properties similar to those of Viadril but with no delay in onset of action, then we may see steroid anaesthetic agents enter into competition with the intravenous barbiturates.

SUMMARY

The properties and clinical use in 212 cases of 21 hydroxy pregnanedione sodium succinate, marketed under the trade name of Viadril, are described. Complications are infrequent, the main disadvantage being a high incidence of thrombophlebitis if concentration of solution is greater than 0.1 per cent.

Viadril in its present form would appear to be most useful in prolonged operations about the head and neck and should not be employed where any degree of muscle relaxation is required.

Post-operative toxic effects of Viadril are minimal and patient impression is good.

It is hoped that a steroid anaesthetic agent without the present disadvantages of Viadril will shortly be produced.

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POSITIVE CONTRAST VENTRICULOGRAPHY*

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In the earlier days of neurosurgery, the localization of cerebral tumours was entirely a clinical matter, and though the approximate position of a number of growths could be forecast by clinical assessment alone, many an operative exposure was made over an area of brain wherein no tumour lay. It rapidly became obvious that more accurate methods of localization were a necessity, and the first really important advance was forthcoming when Dandy (1918) introduced air encephalography. The outlining of the ventricles by air or oxygen has subsequently become, in itself, a specialized subject so that now, if desired, every nook and cranny of the ventricular system can be displayed by careful positioning of the patient combined with meticulously set X-rays. The larger cavities, the lateral and third ventricles, can be outlined almost invariably, but one is liable to encounter difficulties in attempting to visualize those spaces of smaller capacity, the aqueduct of Sylvius and fourth ventricle. The surest method of achieving this is to take films whilst air is in the process of being injected into the lumbar sac with the patient in a sitting position, but this technique is considered by many to be applicable only in the presence of normal intracranial pressure. As one is, in a majority of cases, investigating patients with high pressure, it is often advisable to introduce the air directly by ventricular puncture. It is then essential to coax it into the third ventricle — an easy enough procedure carried out by hanging the head backward with the patient supine (Twining, 1939a and b). After this stage difficulties are liable to start because, to induce air to enter the aqueduct and fourth ventricle, one must turn the patient very rapidly prone, place the head in correct position, fix the cassettes and align the X-ray apparatus accurately, a series of actions which looks easy on paper, but takes time in practice; and whilst time is passing, so too is air which escapes through the aqueduct and fourth ventricle into the subarachnoid space. The nett result is that one does not invariably succeed in displaying the areas aimed at, because they are spaces of small capacity which hold air but momentarily, and unless the films are taken when air is actually travelling through, no diagnostic pictures will be obtained. It is an easier matter to take good films in the presence of hydrocephalus because, in the dilated ventricles above an obstruction, the greater volume of air throws a better shadow; moreover, the fact that there is actual obstruction delays its escape and so one has far more chance of obtaining good films in the time at one's disposal.

Nevertheless, a proportion of failures means that an accurate diagnosis cannot always be made, without which the surgeon is rather hamstrung in his attempts to plan the course of treatment with any degree of confidence. Stimulated by these failures, investigations were made using radio-opaque, oily compounds as positive contrast media in the hope that they would provide more reliable information. The earliest attempts were made with Lipiodol or Thorotrast which proved to have certain disadvantages (Freeman *et alii*, 1936; Critchley, 1953), but ethyl iodophenylundecylate, available as Myodil or Pantopaque, has bland qualities and has been responsible for no known ill effects in our cases. However, one cannot airily dismiss it as being quite harmless after studying the literature on the subject of reactions, both immediate and late, following its use for spinal myelography (Scott and Furlow, 1941; Marcovich *et alii*, 1941; Steinhausen *et alii*, 1944; Ramsay, *et alii*, 1944; Tarlov, 1945; Peacher and Robertson, 1945; Erickson and Van Baaren, 1953; Davies, 1956). There is little doubt that reactions do occur which, very occasionally, have assumed serious proportions, though there is, as yet, nothing to suggest that the passage of Pantopaque through the ventricles has any deleterious effect and consequently, radio-opaque ventriculography has assumed a place in neurosurgical practice.

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Bull's (1950) work in this respect is of major importance and his technique is employed by us, whilst a variant in the posturing technique has recently been described by Horwitz (1956). In selected cases it is of great value and, though it by no means replaces air for routine use, it is used on an increasing scale in the investigation of suspected brainstem and posterior fossa tumours. A particular advantage is that it is far less likely than air to upset the patient who has raised intracranial tension. It is well known that air studies on such patients are frequently followed by an increase of pressure with steady deterioration in condition, so that one must always be prepared to operate as soon as a diagnosis has been reached. On the other hand, the instillation of 1-2 c.c. of radio-opaque dye, which is accompanied by the loss of virtually no cerebro-spinal fluid, does not appear to cause any marked disturbance and one may proceed to operate at leisure if so desired. It is apparent that it must have particular value in the presence of an obstructive brainstem tumour which cannot be surgically removed. Furthermore, the minimal loss of fluid should be potentially less damaging to vision in the presence of chronic, high-grade papilloedema with commencing optic atrophy, an appearance which makes one chary of advising air ventriculography which, in such circumstances, has been known to cause dramatic deterioration in vision.

The successful performance of ventriculography with heavy media requires the same accurate knowledge of head positioning as for air studies, and unless a meticulous routine of manipulations has been planned, the dye is liable to escape into inaccessible corners. The first phase takes place in the operating theatre where a burr-hole is made either in the parieto-occipital position or, preferably, over the anterior horn of one of the lateral ventricles. The incision is then sutured, a dressing applied and the patient taken to the X-ray department where the table has been placed in a vertical position ready for upright screening. With a frontal burr-hole, the patient must sit up with the neck flexed while the ventricle is punctured and 1-2 c.c. of the dye is instilled with the loss of little or no cerebro-spinal fluid. With the parieto-occipital holes it is more complicated. The patient lies prone with the head slightly rotated and flexed so that the medium runs forward into the anterior horn. The patient is then manoeuvred into a sitting position, but the head must be kept continually flexed throughout all changes of position so that the anterior horn remains dependent preventing the dye from running back along the body of the ventricle into the temporal horn. At this stage, i.e. with the patient seated and the dye in the anterior horn, screening commences. The radiologist, protected with gloves, steadies the patient's head and observes the dye through the screen; the head is then slowly extended until the dye flows to the region of the foramen of Monro through which it trickles into the anterior part of the third ventricle. Further extension of the head ensures its passage to the posterior part of this ventricle and the aqueduct where it may be held up by any obstruction. At this stage, the patient is rapidly lowered to a supine position with the head extended, and preparations are made to take films. Lateral and Towne views must be taken in each position from now on. It is as a rule best to commence with the patient flat and then the head can be elevated for further films until eventually a position is reached which allows the dye to flow away out of the fourth ventricle into the spinal theca.

Various difficulties of a technical nature may be encountered throughout. An uncooperative patient must be anaesthetized, which greatly complicates manipulations and it may be very hard to control the head. Once the dye is in the lateral ventricle, difficulty can arise in manoeuvring it through the foramen of Monro, particularly if the latter is not enlarged. In fact, in two cases *(vide infra)* we were unable to get it to enter the third ventricle in sufficient quantity to render the investigation of any use whatsoever; in both, the ventricles were of small size and it seemed probable that the dye was too viscid to negotiate the foramen. Once it has reached the third ventricle, too rapid extension of the head may allow most of it to escape if no obstruction is present. This forces one to rely upon a quick assessment of conditions on screening alone to reach a diagnosis, rather than on films taken at a more leisurely rate. It will therefore be obvious that a trained team is essential if reliable results are to be obtained. Radio-opaque ventriculography is not a practical proposition under

makeshift conditions; good staff work as well as proper equipment must be available.

A number of our cases have proved instructive, some as diagnostic lessons in their own right; others demonstrating that the opaque medium was superior to air; and yet another two indicating the reverse.

FIG. I. The posterior half of the third ventricle is outlined, and the commencement of the aqueduct of Sylvius is seen as a small diverticulum at the postero-inferior angle. No dye would flow beyond this point, indicating a mechanical block at this level.

Case 1

A.D., a boy of 8 years, was admitted to the Department of Neurosurgery, St. Vincent's Hospital, on 7th June, 1955, with a history of four months duration. He complained of persistent headaches, clumsiness of his right hand, unsteadiness of gait with veering to the right side, dysarthria and facial weakness. Examination revealed bilateral papilloedema; asynergic external ocular movements with diplopia; dysarthria and right lower facial weakness. The limbs on the right side were spastic and his grip was weak. All limbs were ataxic, the right more so than the left, and he walked unsteadily on a broad base. Lumbar puncture revealed a pressure of 300 mm. Clinically he presented the picture of an obstructive brainstem glioma and radio-opaque ventriculography seemed to be especially indicated with his high C.S.F. pressure. One and a half cc. of dye were instilled into the lateral ventricle and ran easily into the third, but none would pass through the aqueduct. The lateral film (Fig. I) outlined the posterior half of the ventricle and showed failure of the aqueduct to fill beyond its commencement, whilst the antero-posterior view (Fig. II) revealed enlargement of the ventricle, the lower half of which was shifted towards the right side, findings which confirmed the presence of a midbrain tumour growing up into the left thalamus. Apart from slight drowsiness and a little vomiting for the twenty-four hours succeeding the investigation, there was no change in his condition. He was treated with deep X-ray therapy with intermittent ventricular tapping during the early stages.

FIG. II. The antero-posterior view of the same case revealing a dilated third ventricle, the inferior portion of which is shifted to the right.

Case 2

M.P., a 33-year-old woman, was admitted to the Department on 28th January, 1956. Her symptoms were of recent onset — headaches and vomiting for eight days. The former was worse in the early morning, and intermittently became violent in its severity. On examination, she had bilateral papilloedema, but no other neurological signs. Routine investigations did not aid localization, and no other growths were detected. Air ventriculography revealed a large hydrocephalus involving the lateral and anterior part of the third ventricles. No manipulations succeeded in outlining the posterior third ventricle, and though suspicions were aroused of the existence of a tumour in this region, the interpretation of the films was not at all certain as air in the large lateral ventricles overlay the area under examination. Consequently 2 cc. of Pantopaque were instilled and run into the third ventricle and, with the head hanging, a large filling defect in the upper posterior portion of the third ventricle was clearly defined (Fig. III). A Torkildsen ventriculo-cisternostomy followed by deep X-ray therapy improved her condition, and in October, 1956, she was leading a normal existence with no symptoms.

Case 3

D.P., a male patient aged 22, was admitted to the Department on 3rd April, 1956, with a history of headache and attacks of diplopia for six months, and a more recent onset of nausea, headache and

failing vision. Examination revealed gross papilloedema with acuity of J6 in the left eye and J2 in the right. There were no abnormal neurological signs demonstrable, but he carried his head tilted toward the right. Routine investigations did not aid localization, and lumbar puncture revealed a pressure of 240 mm. of cerebro-spinal fluid. He was a recent migrant who spoke no English and was alarmed at the prospect of surgery, but he agreed to have a burr-hole for ventriculography which was carried out with 2 cc. of Pantopaque. The lateral film outlined the posterior end of the third ventricle, but none flowed into the aqueduct, whilst the antero-posterior view showed a shift to the left of the enlarged ventricle with a filling defect at the right margin, findings consistent with a large right thalamic tumour blocking the aqueduct, and deforming the margin of the dilated ventricle. The actual films resembled those in Case 1. There was no general upset following the procedure, though his diplopia became more persistent and he developed a right abducent weakness. He refused surgery — a Torkildsen ventriculo-cisternostomy would have been advisable — so was treated by deep X-rays and later repatriated.

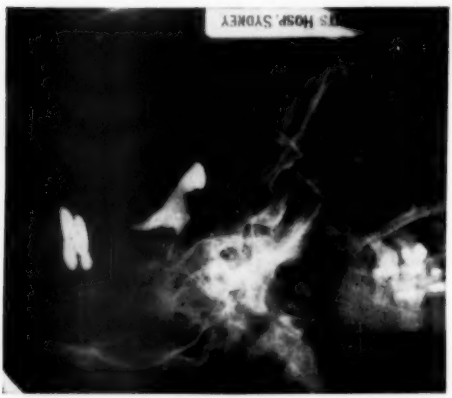

FIG. III. The lateral film in Case 2 taken with the patient lying supine. A large superior filling defect is apparent, suggestive of a tumour growing downward from the corpus callosum. The upper one-half of the aqueduct is clearly outlined and is of normal size.

Case 4

M.C.J., a female patient of 66, was admitted to the Department on 11th June, 1956. She had complained of ataxia for eight months, and suffered with headaches and vomiting for most of this time. Examination revealed a grossly ataxic gait, with nystagmus and intermittent restriction of upward gaze, suggesting a brainstem-quadrigeminal plate tumour. Her lumbar puncture pressure was normal, 120 mm., but 8 cc. of air introduced by the lumbar route was held up at the foramen magnum, and she complained of severe headache at this stage, so that the test was promptly terminated. A few days later ventriculography was carried out using 1½ cc. of Pantopaque as a contrast. The lateral X-ray showed great irregularity of the aqueduct (Fig. IV), which was even more striking in the antero-posterior view (Fig. V). A diagnosis of glioma invading midbrain and pons was made and she derived symptomatic benefit from a course of deep X-ray. She was not at all disturbed by the ventriculogram.

FIG. IV. Lateral film in Case 4 showing gross irregularity of the entire aqueduct.

Case 5

C.T., a girl of 5 years, was originally admitted to the Department on 28th February, 1956. Until two months previously, she had been a vigorous, healthy child, very sure-footed, but then became clumsy with the right arm and her gait became rapidly so unsteady that she could barely walk unsupported. Examination revealed that her head was held tilted constantly to the right and she was grossly ataxic. Lumbar puncture was normal in all respects. Everything pointed to a brainstem tumour, so 1 cc. of Pantopaque was instilled, but practically none could be persuaded to flow into the third ventricle. Air was then run in by lumbar puncture and an admirable display of the ventricles was obtained, the lateral film showing the posterior part of the third ventricle, the aqueduct and the fourth ventricle, whilst the antero-posterior view showed these to be of normal size and position. At this stage, no more could be done, but on clinical grounds a brainstem tumour was still strongly suspected. The parents were told to bring the child for regular neurological observation, but unfortunately failed to do so, only to return six months later with the child hemiplegic, blind and deaf. Pantopaque ventriculography was repeated and the intraventricular pressure was now high, with some dilation of the ventricles. Lateral films showed a tapering block at the upper end of the aqueduct, and the antero-posterior view the dilated third ventricle shifted toward the right side thus confirming the presence of a tumour blocking the aqueduct and extending into the left thalamus. Deep X-ray therapy made no appreciable difference, though she lived several more months. At post-mortem, her tumour was even more extensive than suspected, involving most of the white matter of

the left hemisphere, the left thalamus and caudate nucleus. The lateral and medial geniculate bodies on each side were destroyed and it crossed the midline into the right thalamus. The brainstem itself was not involved by tumour, though the aqueduct was blocked by pressure of the tumour mass. Her films are not reproduced as they resemble those obtained in Case 1.

FIG. V. Antero-posterior film of Case 4 showing the aqueductal distortion which is seen connecting the posterior part of the third ventricle with the upper part of fourth.

Case 6

H.C., a girl of 15, was admitted to the Department on 5th July, 1956. Three weeks previously she had developed headaches associated with vomiting; later she became unsteady on her feet and on the morning of admission had had an epileptic fit. Examination revealed an unco-operative child of subnormal intelligence who appeared to be slightly weak and markedly ataxic in the right limbs. An electroencephalogram showed an excess of generalized slow activity with no evidence of a focal lesion. Three days later, she was unable to walk and fell on trying to take her weight. Clinically, it appeared that there may be a midline lesion and Pantopaque ventriculography was attempted, but again there was a complete failure to get the dye through the foramen of Monro. Once again, air injected by the lumbar route outlined normal third and fourth ventricles with the intervening aqueduct quite perfectly. She suffered no ill effects from this investigation, and in fact rapidly improved to her usual normal state. Her subsequent history suggests that she is an epileptic who developed a Todd's paralysis with rather profound psychological changes after the fit. She is still under observation eight months later and shows no signs of a tumour.

Case 7

S.F., a male patient of 48, was admitted to the Department on 28th September, 1955. His history commenced eighteen months before when he developed headaches following a fall onto his head. His gait became ataxic two months prior to his admission and he complained of numbness on the right side of his face for three weeks. Examination revealed bilateral papilloedema with greatly depressed visual acuity; divergent squint of his left eye; anaesthesia of the entire right trigeminal area; ataxia of the left limbs and an unsteady gait. Ventricular puncture confirmed that there was high intracranial pressure and 1½ cc. of Pantopaque were instilled. The lateral film showed forward displacement of the dilated aqueduct (Fig. VI) which was seen in the antero-posterior film to be displaced to the right (Fig. VII). These films are exactly comparable to those obtained with air in similar cases, and are characteristic of a tumour placed high in the cerebellar hemisphere. At operation, a solid, vascular tumour was found in this situation, but it extended through the upper surface of the cerebellum to adhere to the tentorium. Histologically, it was thought to be a spongioblastoma polare.

FIG. VI. Lateral film of Case 7 showing elongated suprapineal recess above with aqueduct of Sylvius below. The latter is displaced forward giving an appearance of being rather acutely bent, whilst there is a tapering block inferiorly.

Case 8

J.N.F., a man of 48, was admitted to the Department on 22nd August, 1956, with a history of five years listlessness and alteration of personality. For five weeks prior to admission he had had severe left trigeminal pain, mainly in the upper teeth. On examination he was obviously ill, vague and had marked papilloedema. There was a right abducent

paralysis with weakness of the right facial nerve of a peripheral type. He was becoming increasingly drowsy and, as the signs seemed to indicate a pontine tumour, Pantopaque ventriculography was advised. Two cc. of dye were injected into the left lateral ventricle, and on screening, a deformity of the anterior horn was noticed. Consequently films were taken with the patient prone, and the lateral film shows an elevation of the anterior horn with posterior displacement of the anterior end of the third ventricle (Fig. VIII). The postero-anterior view shows a shift of the left lateral and third ventricles across the midline (Fig. IX). These findings were totally unexpected indicating a left subfrontal tumour, and had any hemispheral lesion been suspected, air ventriculography would have been the method employed. It was fortunate that we were not misled in the circumstances, for had the dye been put into the right ventricle, considerable confusion might well have resulted. As it turned out, localization was accurate and an angiogram outlined a highly vascular, circumscribed tumour which, at craniotomy, proved to be a malignant glioma. Frontal lobectomy followed by deep X-ray therapy relieved his symptoms temporarily.

FIG. VII. Antero-posterior film of Case 7 showing dilated third ventricle with the blocked aqueduct displaced towards the right side.

Case 9

P.C., a female patient of 35, was admitted to the Department on 24th August, 1956. Fifteen months previously, a gland had been removed from her neck which, histologically, was characteristic of Hodgkin's disease. She had not had any further illness until one week prior to admission when a mild, intermittent fever had developed. During the ensuing week she had become confused and uncooperative, with occasional incontinence of urine. Lumbar puncture showed no increase of pressure, whilst the fluid contained a moderate increase of cells and protein with a small reduction of chlorides, findings suggestive, but not diagnostic, of tuberculous meningitis. Within a further forty-eight hours she had lapsed into a light coma and another puncture revealed an enormously raised pressure, leading to a suspicion that there might be a mechanical block in the posterior fossa. Air ventriculography was therefore carried out and displayed a moderate hydrocephalus of the lateral and third ventricles but, despite repeated attempts, no air could be manipulated into the aqueduct or fourth ventricle. On these findings, there existed a clear indication for posterior fossa exploration, but we were loth to proceed in the face of her poor general condition. Therefore, 2 cc. of Pantopaque were instilled and a series of films taken which outlined a normal aqueduct and fourth ventricle. Finally the dye was successfully run through the latter into the spinal subarachnoid space. This information was invaluable, and obviated a major surgical procedure which would have been carried out had full reliance been placed upon the air studies. Her subsequent course was through a stage of two weeks marked improvement, followed by a severe relapse and death. Post-mortem proved her to have tuberculous meningitis, and there were no microscopic ependymal changes inconsistent with her infection, there having been apparently no reaction to the Pantopaque.

FIG. VIII. Lateral film in Case 8 showing the filling defect in the floor of the anterior horn of the left lateral ventricle, whilst the anterior part of the third ventricle is displaced upwards and backwards.

These cases show the value of radio-opaque dyes in ventriculography in certain instances, notably those with obstructive lesions in or encroaching upon the posterior part of the

third ventricle, aqueduct and fourth ventricle. It may be of use when air has failed to provide a diagnosis or has given cause for confusion, and likewise it may be employed instead of air in the pursuit of a midline block. It has caused no known ill effect on any of our cases, but it has shortcomings in that it may fail to pass through an undilated foramen of Monro. On the whole, we are impressed with its value in selected cases, and have observed no severe reactions nor injurious effects following its use.

FIG. IX. Postero-anterior film of Case 8 showing the shift towards the right of the lateral and third ventricle with distortion of the inferior surface of the anterior horn of the lateral ventricle.

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A STUDY OF CARCINOMA OF THE COLON USING AN HISTOCHEMICAL TECHNIQUE

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THE recognition of malignant cells by some clearly distinctive feature has been a matter for continuous enquiry by the histopathologist and the dream of the surgeon who would like an unequivocal method of determining the precise nature of the tissues on which he is operating.

The problem has been attacked by the use of many special stains and the examination of cells by various physical techniques. The desirability of some clearly discriminating method in cases of hyperplasia of the breast or prostate, polyps of the intestine, adenomata of the thyroid and various hyperplasias of the skin, to mention only some, has been recognized since the beginning of the century. The urgency of the problem, in recent times, has been high-lighted by the attention that has been given to such states as, for example, carcinoma *in situ* in the cervix uteri.

All current methods of staining are of but limited and often poorly-defined effectiveness. Nucleus is clearly differentiated from cytoplasm and various secretions may be rendered recognizable, but slight differences of protoplasmic structure or chemical constitution are not demonstrable by these techniques. Even the more specific stains are extremely limited in their application since their localization is determined either by general physico-chemical factors such as hydrogen ion concentration or by the occurrence of particular chemical configurations, which are to be found in different areas, and is unrelated to the pathological nature of the cell or tissue.

The search for a method depending on serological differences between the malignant and the normal tissue arose, toward the end of the last century from the, then, not unnatural premise that the neoplastic cells were essentially different — that the tumour was something in the nature of a parasite. This concept proved to be an illusion but gradually minor discrepancies became sufficiently understood and defined to enable them to be demonstrated.

The distinction was first made in the experimental animal. In some forms of chemical carcinogenesis, the carcinogen is bound to certain protoplasmic proteins. Proteins with similar properties (mobilities) can be demonstrated electrophoretically to be absent from the malignant cell and this difference has been confirmed histochemically. This and related methods have been applied to a group of tumours in man and the results of the observations are given here.

Historical

The opinion that certain chemical groups can be introduced into the antibody molecule without altering its potency or destroying its antigenicity has been well established.

Reiner (1930) coupled pneumococcal antisera wth diazotized atoxyl and found that the agglutination titres were unchanged. Heidelberger, Kendal and Soo Hoo (1933) and Marrack (1934) labelled antibodies by making R-salt-azo-benzidine-azo-typhoid and cholera antisera and showed that the respective organisms were specifically agglutinated and coloured red. However, the red colour of the antigen-antibody complex was barely detectable microscopically.

Some years later, Creech and Jones (1941) found that they could conjugate horse serum albumin with certain aromatic isocyanates and that this conjugation caused no alteration in the potency nor in the immunological specificity of the serum. Using this finding as a basis, Coons *et alii* (1942) conceived the idea of using fluorescein isocyanate for coupling, as this would give a green fluorescence which would be easily detectable microscopically. Eventually Coons and Kaplan (1950) perfected and standardized this technique and successfully used it to demonstrate the localization of pneumococcal antigenic material.

Weiler (1952, 1956a and b) using this fluorescence antibody technique, demonstrated differential staining of normal rat liver and normal hamster kidney as compared with experimentally produced rat hepatomata and hamster kidney carcinoma. He interpreted his results as an indication that the neoplastic change involved the loss of the "organ specific antigen" from the cell. Hughes *et alii* (1957), also working with experimentally produced rat hepatoma, found that identical differential staining could be produced by fluorescent normal rabbit globulin and that this differential staining was independent of the presence of "organ specific fluorescent antibodies" in the serum. Cells in the actual process of mitosis have been demonstrated to fluoresce (Louis, 1957b) so that the phenomenon of loss of fluorescence appears to be peculiar to the neoplastic state itself.

METHOD AND MATERIALS

Sera were prepared according to the methods of Weiler (1956a and b) by injecting rabbits with homogenates of mucosae from the caecum, transverse colon, descending colon, sigmoid and rectum. Doses of 1-2 mls. of a 25 per cent. homogenate of each segment of the bowel in 0.25M sucrose was injected into individual adult rabbits three times per week for three weeks. The globulin fractions of the antisera were coupled with fluorescein isocyanate (isomer I) using the method of Coons and Kaplan (1950). Human liver particulates were used for absorptions. For each absorption the sera and the liver particles were incubated for one hour at 37°C and then overnight in a cold room at 0-2°C. Following clarification by centrifugation, the fluorescent sera were reabsorbed three times, as above, in each case using fresh liver particles.

Only fresh biopsy material was used for the preparation of tissue sections for microscopy. In all cases a small piece, not more than 4 mm. thick, was selected from the edge of the tumour. This was immediately snap frozen by dropping into a tube of isopentane, kept at –70°C, in a stoppered Dewar flask containing an ethanol dry-ice mixture. Unfixed frozen sections were cut at 5-7 μ by a method already described (Louis, 1957a), dried in a cold room at 0-2°C with the help of a fan for 1½-2 hours, re-immersed in cold absolute alcohol at –20°C for 10-15 minutes and again dried in the cold room overnight.

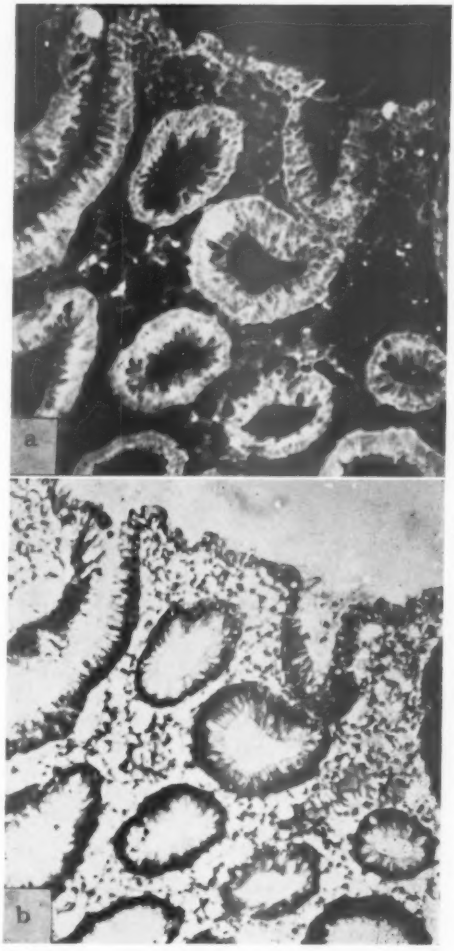

FIG. I. Normal colonic mucosa. (a) Unfixed frozen section stained with fluorescein-globulin complex showing fluorescing epithelial cells; nuclei and vacuoles do not fluoresce. (b) Same area subsequently fixed in formalin and stained with haematoxylin and eosin for comparison with (a). (x 200)

Prior to staining, the unbound fluorescein and its derivatives were extracted with ethyl acetate (Dineen and Ada, 1957). The sections were then stained with fluorescent antiserum for 15 minutes at room temperature, washed in three changes of buffered saline pH 7.3

for 10 minutes and then examined with a fluorescence microscope. Sections of tumours from each section of the large bowel were stained with:

(i) conjugated human colonic mucosa antiserum;

(ii) conjugated normal rabbit globulin;

(iii) conjugated anti-tumour rabbit globulin;

(iv) conjugated antisera from each segment of the bowel.

First the sections were examined using the fluorescence microscope and representative areas photographed. Then these sections were fixed immediately in 10 per cent. formol-saline, stained with haematoxylin and eosin and, for comparison, the same areas photographed again with visible light (Figs. I, IV and VI).

RESULTS

The staining characteristics of normal colonic mucosa were investigated by ultraviolet microscopy both in its natural state and after staining with a fluorescein-globulin complex. The tissues were examined in the unstained state in order to exclude any intrinsic fluorescence present independently of the use of the stain. Although most tissues show fluorescence, they usually do not fluoresce brightly and, in any case, they commonly fluoresce in colours different from those observed after staining with the fluorescein-globulin complex.

The general finding, with all the preparations of conjugated sera used, was that the glandular epithelium of the colonic mucosa emitted a bright green fluorescence after staining with the fluorescein-globulin complex. All sections examined showed characteristic intracellular localization of this fluorescence in which the cytoplasm and not the nucleus fluoresced. This distribution created a halo effect in the cells around their nuclei and vacuoles (Fig. I). However, whether on the surface of the mucosa or within the lumina of the glands, mucin masks the cellular detail owing to its strong affinity for fluorescein and its derivatives. As a rule the connective tissue failed to fluoresce except for small flecks of bright yellow autofluorescence due, presumably, to elastic tissue fibres. This bright yellow autofluorescence, was also a constant feature of the walls of the blood vessels where it was localized to the region of the elastic laminae (Fig. II) and was not influenced, after staining the tissue section, by the conjugated serum.

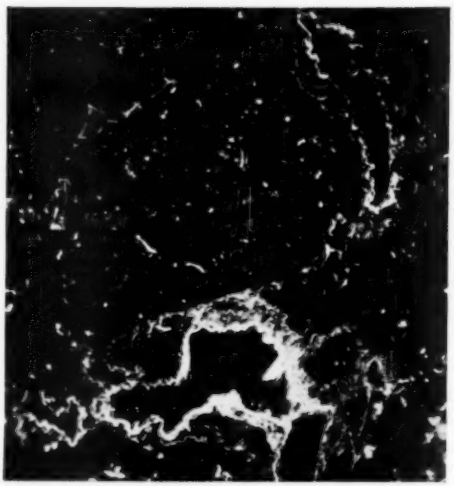

FIG. II. Fluorescence photomicrograph showing vessels in bowel wall. The elastic tissue emits a natural yellow fluorescence which is non-specific. (x 200)

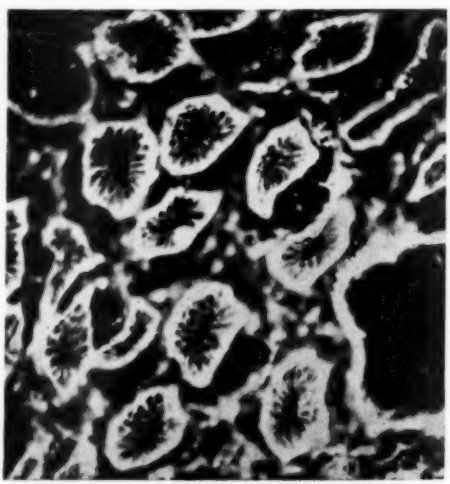

FIG. III. Single polyp. Unfixed frozen section stained with fluorescein-globulin complex showing a bright and even fluorescence of all the epithelial cells. (x 160)

Several single pedunculated polyps, which ranged from ½-2 cm. in diameter and which proved to be benign on histological examination, were examined. The tissues of these polyps stained similarly to those of the normal mucosa, namely, the lining epithelium emitted a bright green fluorescence and then only after staining with the fluorescent serum (Fig. III).

One case of multiple polyposis was investigated. This was a surgical specimen from a girl aged 26 years who had had diarrhoea consisting of 5 bowel actions per day, mainly mucus occasionally blood stained, for the past two years. Her father died at the age of 35 from a carcinoma arising in pre-existing multiple polyposis of the bowel. Proctoscopic and sigmoidoscopic examinations showed the presence of masses of papillary and pedunculated polyps with an occasional sessile one. A barium enema disclosed findings typical of multiple polyposis. At operation the whole rectum, large bowel and terminal two feet of the small bowel were found to contain polyps; however, those in the small bowel were of different appearance being less raised and no more than 3 mm. in diameter.

The characteristic microscopic findings in this case were multiple patchy areas of diminished staining involving groups of mucosal cells which appeared histologically similar to their neighbours after subsequent staining with haematoxylin and eosin (Fig. IV). These areas were more evident on the surface of the polyps than in the deeper glands. They were demonstrated with all the conjugated sera listed above with equal degrees of distinctness in each case but there was no significant difference when the unabsorbed serum was used which contained free fluorescein and derivatives.

Finally 20 cases of carcinoma of the rectum and large bowel were investigated (Table 1). In all cases similar results were obtained, namely, normal mucosa fluoresced brightly and uniformly whereas the malignant tissue failed to fluoresce (Figs. VI and VIII). After staining with haematoxylin and eosin the fluorescing areas appeared benign while those not fluorescing were the characteristic malignant tissue (Figs. VIb and VIIIb). Again the results were the same irrespective of the specificity of the serum, provided free fluorescein derivatives were extracted from the serum before use. Most of the tumours produced some mucus. This mucus, like normal mucus, had a high affinity for the fluorescein-globulin complexes used and when present stained brightly. This staining has to be distinguished from the staining characteristic of the cytoplasm itself which was found only in the cells of the non-neoplastic mucosa in contrast to the cells of the neoplastic mucosa.

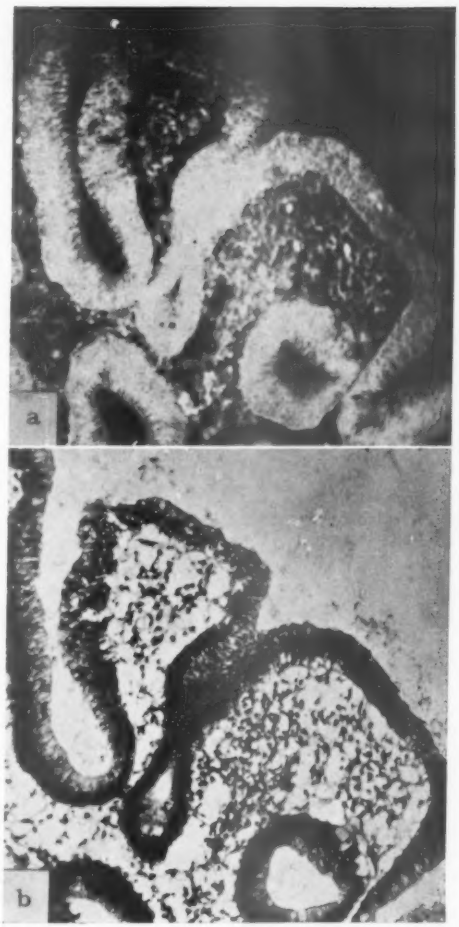

FIG. IV. Multiple polyposis. (a) Unfixed frozen section stained with fluorescein-globulin complex showing areas of diminished fluorescence on the surface. (b) Same area subsequently fixed in formalin and stained with haematoxylin and eosin for comparison with (a). (x 350)

TABLE 1

The results of fluorescence staining in a series of 20 carcinomata of the colon and 4 polyps. The single polyps stained (and fluoresced in ultra-violet light) in the same way as did normal tissue. The polyp from the case of multiple polyposis showed areas of "loss" of staining. The cells of all the twenty malignant tumours failed to stain.

Condition	*Site*	*Histological Type*	*No. Examined*	*Specific Fluorescence*
Carcinoma	Rectum	Adenocarcinoma	5	Nil
Carcinoma	Sigmoid colon	Adenocarcinoma Mucoadenocarcinoma	3 2	Nil Nil
Carcinoma	Ascending colon	Adenocarcinoma	2	Nil
Carcinoma	Transverse colon	Adenocarcinoma	4	Nil
Carcinoma	Caecum	Adenocarcinoma Mucoadenocarcinoma	3 1	Nil Nil
Single polyps	Rectum and Sigmoid	Benign	3	Uniform
Multiple polyposis	Rectum Colon Small bowel	Benign	1	Patchy

FIG. V. Margin of carcinoma of colon. Low power photomicrograph showing tumour tissue on the right and normal glands on the left. The area in the rectangle is shown in Fig. VI. Frozen section stained with haematoxylin and eosin. (x 60)

DISCUSSION

The sharp distinction between the cells of carcinoma of the colon and those of the non-neoplastic mucosa of the bowel, demonstrated in this type of study, is an arresting phenomenon which demands not only confirmation in a large series of cases but also comparison with results obtained by the use of different staining methods. A series of 20 cases has been examined with consistent results, namely, a uniform failure of the neoplastic tissue to stain. Since the phenomenon was initially regarded by Weiler (1952, 1956a and b) as an antigen-antibody reaction and, therefore, of sharp specificity, antisera were made to each part of the large bowel mucosa. As expected no significant difference was found by using preparation of the different anatomical segments as antigens.

It is well known that many tissues have a natural fluorescence and, throughout this study, it has been appreciated that two types of phenomena must be considered: first, the natural fluorescence of a tissue (autofluorescence) and, secondly, the superimposed

fluorescence of a staining material (secondary fluorescence). The distinction between these is established easily by the use of adequate controls. Furthermore, the different types of fluorescence help to distinguish the various tissues. For these reasons emphasis was laid on the special significance of green fluorescence. Naturally occurring green fluorescence of tissues is extremely rare whilst other fluorescence, particularly of a blue or yellow colour, commonly occurs naturally. It is not clear, from many of the statements in the literature, whether adequate attention has been paid to this aspect of the problem. In the present series of cases the occurrence of various types of fluorescence — particularly in the walls of the blood vessels — has been noted but special efforts were made to avoid confusing these with the characteristic green fluorescence seen in tissues stained with the fluorescein-globulin complex.

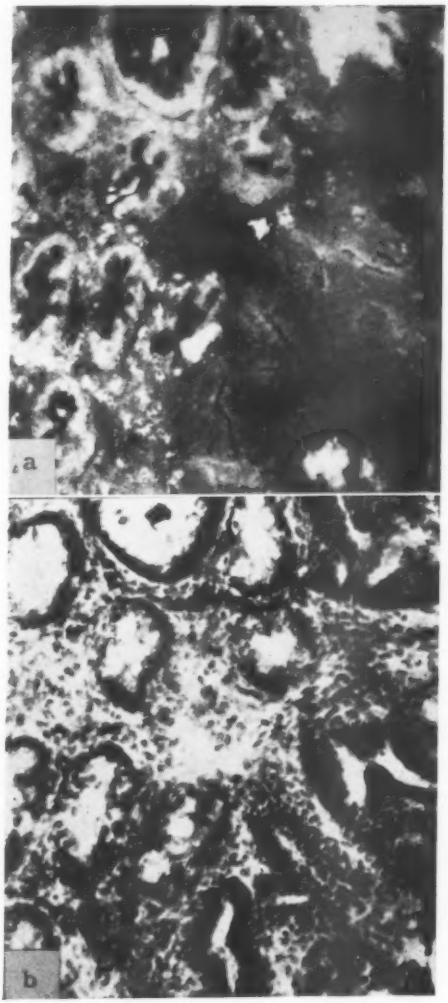

FIG. VI. The rectangular area in Fig. V. (a) Unfixed frozen section stained with fluorescein-globulin complex normal glands fluorescing on the left and non-fluorescing tumour tissue on the right. (b) Same area subsequently fixed in formalin and stained with haematoxylin and eosin for comparison with (a). (x 200)

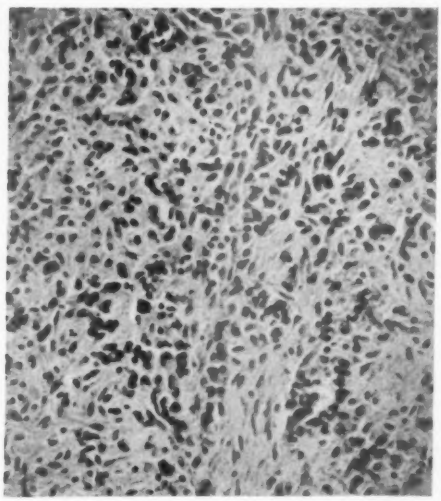

FIG. VII. Carcinoma of colon. Low power photomicrograph showing the highly anaplastic character of the tumour. (x 120)

The observations described in this paper were restricted, at first, to experimentally induced rat hepatomata following the ingestion of the carcinogen 4-dimethylaminoazobenzene. The phenomenon of differential staining is related to fixation of the carcinogen in the cytoplasm of the cells of the affected tissue and it seemed probable that similar relationships might be found with other carcinogens. It was soon found to apply to liver tumours induced by related carcinogens and later to cutaneous neoplasms experimentally induced using substances which are also concentrated in the epithelial cells, such as 1,2,5,6-dibenzanthracene (Wiest and Heidelberger, 1953)

and 3,4-benzpyrene (Graffi, 1940; Hamperl and Graffi, 1941; Hamperl, Graffi and Langer, 1942).

The method was applied by the writer to naturally occurring tumours in animals, to a series of human tissues and to several groups of malignant neoplasms in man. The uniformly comparable results quickly suggested the applicability of the method to a thorough study of neoplastic conditions in man. Of the various problems presenting themselves, an investigation of a series of cases of carcinoma of the colon was completed first owing to the relative frequency of this condition in this country.

Already some studies have been made in man though the results have not been clear-cut. Hiramoto and Pressman (1957) studied the characteristics of an "infiltrating carcinoma" of the skin and a melanoma. They showed that both these tumours fluoresced after appropriate staining. In the short report presented, details of histological characteristics were not available. The extreme difficulty in some cases of distinguishing between a true neoplasm and a condition of quite a different nature, but closely resembling it morphologically, is well recognized by pathologists. That molluscum sebaceum or molluscum pseudo-carcinomatosum has been segregated from true neoplasms of the skin only in recent years is a clear indication of this difficulty. Personal observations indicate that neoplasms do not fluoresce. The distinction between some actively growing moles and melanomata is also difficult. However, the problem encountered personally has been a failure of some presumably innocent nodules to stain uniformly rather than the reverse. Present investigations promise to clarify these points.

The staining of altered connective tissue stroma in various "rheumatic" conditions has been investigated by Scott (1957). Characteristic fluorescence has been found in some degenerative states. However, adequate distinctions do not appear to have been made between the different kinds of fluorescence mentioned above. It cannot be overemphasized that fluorescence is an optical phenomenon depending on different factors in different cases. In all tumours examined, both experimental and naturally occurring, the difference from normal tissue has been clear and well defined. Since the difference appears to be due to the absence from the malignant cells of a protein complex, it seems probable that such a change would not necessarily be an abrupt one. Indeed, recent investigations indicate that the final form of

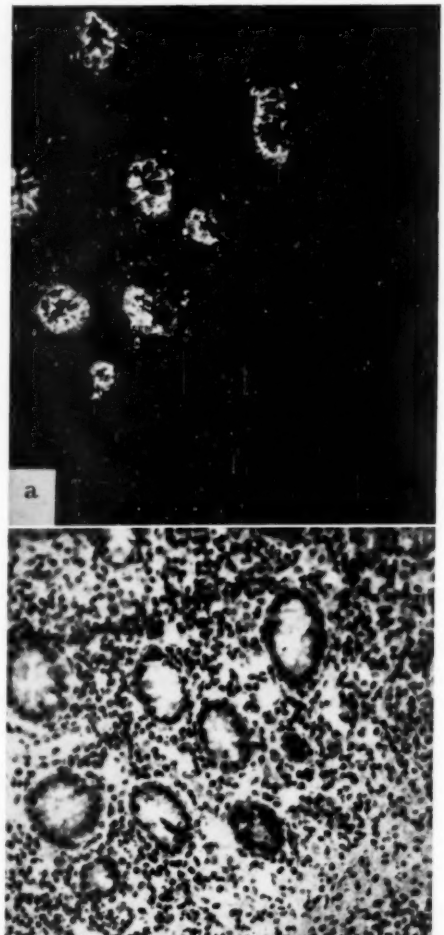

FIG. VIII. Margin of carcinoma of colon from Fig. VII. (a) Unfixed frozen section stained with fluorescein-globulin complex and showing fluorescence of the glands at the edge of the tumour. (b) Same area subsequently fixed in formalin and stained with haematoxylin and eosin for comparison with (a). Note the gland with the deeply staining nuclei does not fluoresce. (x 120)

tumours is due to a series of changes (mutations). This would indicate that gradations in the amount of significant protein might be found in cells in the region of the growth, that is to say, it might be possible to demonstrate a pre-malignant stage histochemically. Such altered areas were first demonstrated in livers of rats fed 4-dimethylaminoazobenzene, at a stage before the tumour has developed. Histochemically areas of diminished or absent staining are found amongst the liver cells. These may be small or large ranging from a group of a few cells up to almost a whole lobule. That these areas, which are referred to as "islands of loss" constitute a "precancerous" state is shown by the inevitable formation of fully developed tumours at a later date.

This observation indicates that the staining characteristics of a cell may not necessarily show that it is neoplastic but it is clear that a non-staining cell is either neoplastic or potentially neoplastic. Taken together with other features such as the general conformation of the tumour tissue and the morphology of the cells, the degree of departure from the normal tissue may be assessed. Thus the value of this method is not as a means of distinguishing between a frank neoplasm and a precancerous condition but rather between any of the neoplastic group from normal or hyperplastic states. The distinction between frank and potential growths may be made by correlation with other features such as those mentioned above.

The polyps of mucous membrane have raised many problems as to their nature and particularly their relation to carcinoma. In the colon a close clinical relation has been established between the presence of polyps (particularly in polyposis coli) and the subsequent development of carcinoma. This is well shown in cases examined post-mortem (Stewart, 1931) and especially in a series of consecutive tumours observed by Dukes (1926) in which polyps were found in 75 per cent. of cases. The carcinoma does not necessarily develop at the site of a polyp indicating that the change is spread over an area of mucosa rather than being localized to the region of the polyp. This hypothesis of a "field of origin" of tumour formation is strongly supported, in the colon, by cases in which a carcinoma develops away from actual polyps or after their removal.

In experimental conditions, administration of a carcinogen is followed first by the formation of polyps and later by the development of malignancy which may be either in or between the polyps.

The histological appearances of polyps also are significant here. Commonly there is considerable departure from the normal structure of the glands: an increase in the number of cells, variation in cell size and hyperchromatism of nuclei. Such features may be observed throughout the polyp or may be found only in some parts of the tissue. They constitute a serious histopathological problem since the form of these cells strongly suggests a malignant condition. At the same time experience shows that many of these polyps, at this time, are not actually neoplastic. Thus it is apparent that the simple morphological criteria do not provide the key to their true nature.

The present method of study indicates that the polyp is different from the malignant growth. The tissues of the polyp, in general, resemble the normal mucous membrane in that it fluoresces brightly after staining with the fluorescein-globulin complex. At the same time the potentially malignant character of some of the cells is shown by areas or islands of loss of staining. These resemble those seen in the liver in experimental chemical carcinogenesis.

This present method of histochemical investigation thus may be of some academic interest in showing a distinction between normal and malignant tissue, but it certainly promises to be of immediate significance in indicating the nature of the tissues of a polyp which, by all current methods of study, are indeterminate in character. It shows such remarkable potentialities for the elucidation of many of our everyday queries that it is essential that its significance be clearly determined. This evaluation of the method is not necessarily easy.

At first it was thought that the reaction was a simple antigen-antibody phenomenon. This has been an interpretation of many occurrences ever since the ingenious diagrams of Ehrlich captured the credulity of students of the last few decades. However, the simple expedient of using a fluorescein-globulin complex obtained from an animal which had not received injections of tissue homogenates

— a normal control which might be expected to be applied in any scientific experiment — has shown (Hughes *et alii*, 1957) that such non-antigenic material produces results identical with those observed after the use of a specially prepared "organ specific" antiserum stain.

This immediately raises the question of the nature of this phenomenon. The particular protein concerned has been demonstrated to have special physico-chemical characteristics, so that the histochemical changes come to lie on a simple physico-chemical plane rather than one of a complex biological nature.

The significance of this direct physico-chemical rather than serological basis for the method has two important implications. First, the mode of interaction of the two components — the protein complex of the cell and the fluorescein-globulin complex of the stain — is susceptible of attack by modern methods. Secondly, the technique is brought into line with many other modern histochemical procedures. The simplification effected by the elimination of the specially prepared "organ specific" antisera which are peculiar to each tissue brings much nearer the time when this method, or some modification of it, will be available as a routine procedure for surgical material.

ACKNOWLEDGEMENTS

My thanks are due to the honorary staffs of the Royal Melbourne, Alfred, St. Vincent's and Prince Henry's Hospitals. I am particularly indebted to Mr. E. S. R. Hughes for supplying the case of multiple polyposis (amongst others).

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ANAESTHESIA FOR BRONCHOSCOPY AND BRONCHOGRAMS IN CHILDREN

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Introduction

In recent years the need for a reliable and safe anaesthetic technique for children undergoing investigation for various respiratory conditions has increased considerably. It is required in such conditions as the early diagnosis of bronchiectasis, the removal of various foreign bodies which have been inhaled into the air passages, or for the early diagnosis of primary tuberculous hilar glands, which may be eroding the bronchi or causing strictures.

The margin between a successful administration and disaster is often fairly narrow in these cases and they provide a challenge to the skill of the anaesthetist.

Requirements

There are several requirements to be met if these procedures are to be carried out in comparative safety. Firstly, non-explosive agents must be used wherever possible in view of the danger of sparking from the X-ray plant. Methods of inducing the child with ether in an ante-room and hoping that the effect will last long enough to complete the investigation are mentioned only to be condemned.

There must be adequate oxygenation of the patient throughout the procedures and no prolonged periods of high carbon dioxide tension. These patients are often poor risk cases who do not tolerate any physiological trespass at all well.

Radiologists have various requirements which must be met in order to obtain the best results when taking bronchograms. Most desire some form of apnoeic technique in order to obtain clarity of pictures, yet despite this there should be no marked increase in intrapulmonary pressures, or the radio-opaque medium is rapidly dispersed into the smaller bronchioles with resulting deterioration in the X-ray pictures.

It is important to remove as much as possible of the secretions from the tracheobronchial tree before radiography, and to aspirate any residual secretions plus the added radio-opaque material at the completion of the procedure.

Finally the technique employed for these manoeuvres should allow a rapid return of the protective cough reflex at the conclusion of the proceedings.

Difficulties

As mentioned before we are often dealing with poor risk and debilitated children who do not tolerate any faults in anaesthetic technique. Being children there are the usual intubation difficulties arising from the small size and the position of the larynx and trachea. There is often some difficulty in adequately oxygenating these patients, due both to their excess secretions and the addition of the radio-opaque medium into the tracheo-bronchial tree.

During screening or the taking of X-ray plates, the anaesthetist is often working in total darkness or at most, with a dim red light to help him. In addition to this the patient undergoes marked changes of posture during the manoeuvres necessary to get the radio-opaque medium into the orifices of the various bronchi, and may suffer a profound hypotension as a result of this.

Post-operatively the tendency of the vocal cords to go into spasm must be kept in mind as the subsequent period of hypoxia may prove fatal for the child.

Finally, owing to the size of these patients, there is often difficulty in finding suitable veins for injection, or having found one, difficulty in keeping the needle in place in the vein during various changes in posture.

TECHNIQUE

The following is a technique which has been evolved after many trials and tribulations and which has been found to be satisfactory for the majority of cases.

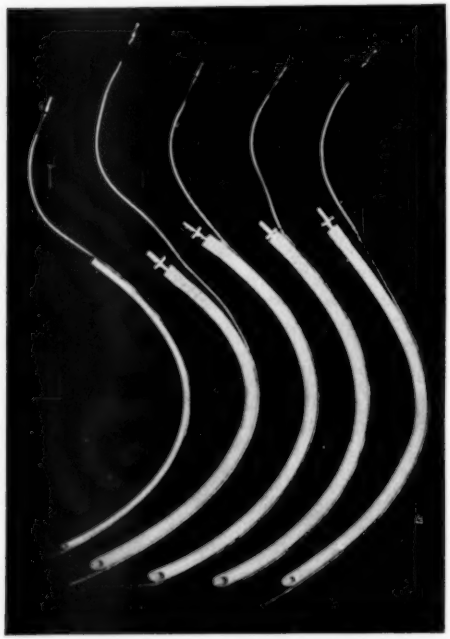

FIG. 1

Premedication

For children 1 to 6 years of age, rectal thiopentone (1 gram per 50 lb. wt.) is given in the ward half an hour beforehand, plus atropine gr. 1/100 as soon as the child is asleep.

For children from 6 to 12 years, omnopon and scopolamine, dose for weight (according to Shiela Anderson's Tables), is given one hour pre-operatively.

Induction

In most cases the patients are asleep following the rectal thiopentone. If however they react to a needle prick strongly, a further 2-4 ccs. of 2½ per cent. thiopentone are injected intravenously using a 25 gauge needle (a vein on the back of the hand or ankle are the best in this age group).

If there is no reaction from the intravenous prick 10 to 50 mgm. of succinyl-choline chloride are given and the patient inflated gently with oxygen. The cords and trachea are then sprayed with 2 per cent. Lignocaine and the patient reinflated.

Diagnostic bronchoscopy and suction is then carried out with oxygen supplied to the side tube of the bronchoscope and manual compression of the chest if respiration are still inadequate.

At the conclusion of the bronchoscopy another 10 to 15 mgm. of succinyl-choline chloride is given and the patient again fully oxygenated. A special bronchography endotracheal tube is inserted (see Fig. 1) and its position checked by screening.

These are portex tubes of varying sizes with a small vinyl portex side tube with vinyl portex cement. The side tubes for carrying the opaque medium are attached to the convex surface of the endotracheal tubes for ease in introducing through the cords. The tip of the side tube projects ¼" beyond the distal end of the endotracheal tube to keep the dye away from the opening.

Maintenance

The patient is maintained with controlled respiration with nitrous oxide and oxygen 2:1 on a semi-open circuit (making sure that the lungs are not over-inflated or that the intrapulmonary pressures are not greatly increased). Additional small increments of succinyl-choline chloride are given as required.

The opaque medium is given from a syringe via the side tube, the medium being watery and the dose usually 1 cc. per side, per year. After introduction of the dye, the patient is postured according to the side and segment. Using this technique has the following two main advantages:

1. Very small amounts of dye are required in order to get good pictures.
2. Being an apnoeic technique, there is no blurring of the picture resulting from chest movements during the exposure time.

In the 6 to 12 months age group, in order to get an apnoeic technique, advantage has been taken of intra-muscular succinyl-choline chloride 2 mg. per lb. The onset of apnoea

is usually in one to two minutes and the return of full respiratory exchange from five to fifteen minutes, and so far we have not met with any difficulties or worries from prolonged action.

Extubation

Before removing the endotracheal tube, the opportunity is taken to suck out the nasal fossae and pharynx. A fine polythene catheter is also inserted through the endotracheal tube to remove as much of the dye as possible. The succinyl-choline chloride syringe is left in position during extubation, in case a severe laryngeal spasm occurs, when a further small amount may be given, and the patient inflated, with oxygen.

Post-operative troubles

If there should be excess secretions in the tracheo-bronchial tree or extra quantities of radio-opaque medium have had to be given in order to obtain satisfactory X-rays, the child may require bronchoscopy and removal of the secretions by suction.

Laryngeal spasm is particularly liable to occur post-operatively due to the irritant effect of the secretions on the vocal cords, and the child should not be allowed to return to the ward until the anaesthetist is satisfied that all danger of this occurrence is past.

If the anaesthetist has been over enthusiastic with his inflation of the patient with oxygen, he may find that the stomach has become markedly distended, with consequent interference with the child's tidal exchange. This can be easily corrected by manual compression of the abdomen.

PRACTICAL POINTS

The anaesthetist by various manoeuvres can help his radiological colleagues to obtain better diagnostic X-rays. He can, for example, by making the best use of posture and the aid of gravity, run the radio-opaque medium into the segment or lobe required. Often the judicious use of percussion of the chest wall will aid the introduction of the dye into the required orifice. It is not wise, however, to persist in trying to fill a segment, as, if the above procedures do not succeed, the cause is usually pathological, and persistence will only lead to flooding of the lobe. It is sometimes possible, if there is a stricture of the right or left main bronchus, to pass a fine piece of polythene tubing through it and allow the dye to outline the lower lobes.

SUMMARY

1. A method of anaesthesia for bronchoscopy and bronchograms in children is given.

2. The advantages of an apnoeic technique in the production of better bronchograms, good oxygenation of the patient, and prevention of bronchospasm and laryngeal spasm during the introduction and removal of the opaque medium is explained.

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CARCINOMATOUS URETERIC OBSTRUCTION THIRTY YEARS AFTER URETERO-SIGMOIDOSTOMY

By L. L. WILSON

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IMPLANTATION of the ureters into the large bowel was first recorded in 1852 by Simon and has been in universal practice for the last thirty years. The present brief note concerns an extremely satisfactory result from a bilateral uretero-sigmoidostomy performed by Sir Henry Newland in 1926.

Clinical record

The patient, a married woman aged 47, had incontinence of urine since birth, due to a congenital abnormality. At the age of 16 in 1926, she had both ureters implanted into the sigmoid colon on separate occasions. Shortly thereafter she developed an infection in the left kidney, which persisted for many years, necessitating the termination of her first pregnancy. Subsequently she enjoyed good health, and was able to have three children.

Early in 1956 she developed a carcinoma of the sigmoid colon, in the region of the ureteric implants. This was removed in April of that year. After the operation she never fully recovered and was admitted to the Royal Adelaide Hospital on 20th February, 1957, with signs of intestinal obstruction complicated by uraemia.

At operation a combined small and large bowel obstruction was found. The former was due to adhesions, and the latter to a probable recurrence of the carcinoma in the sigmoid colon. A small bowel resection was performed, but she died on 20th March, 1957.

The resected specimen from the last operation showed no lesion in the intestinal lumen, but anaplastic cancer cells evoking some fibrosis were present in the adjacent fat and in the outer layer of the intestinal muscle.

Autopsy findings

Autopsy was performed three hours after death. The relevant findings were:—

Both kidneys and ureters were removed together with a portion of sigmoid colon. The left kidney was 13 cms. long and the pelvis and ureter were considerably dilated. The kidney consisted of only a shell of renal tissue 0.5 cm. in width, there being a gross renal hydronephrosis. The terminal portion of the left ureter was constricted by fibrous tissue, and the point of entry into the bowel could not be demonstrated.

The right kidney was also 13 cms. long. The pelvis and ureter were dilated, but to a less extent than the left. Section of the kidney revealed quite a marked renal hydronephrosis. The cortex was 2 cms. thick, but the medulla was considerably reduced. The lower third of the ureter was again tightly constricted by fibrous tissue, but the point of entry into the bowel could be seen. This was a small raised nodule of bowel mucosa 1 cm. in length with a pin-point orifice, through which urine could be expelled.

The liver was enlarged, but there were no secondary deposits. There were several enlarged hard glands in the mesentery and in the neighbourhood of the ureteric implants. The bladder, uterus and vagina showed no abnormality.

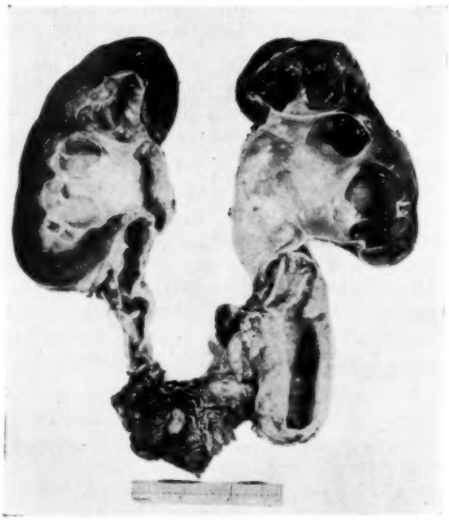

FIG. I. Photograph of the autopsy specimen, showing the bilateral hydronephrosis. The white nodule in the sigmoid colon is the point of entry of the patent right ureter.

Histological sections from the tissue surrounding the occluded left ureter and neighbouring lymph glands, showed a scattering of anaplastic carcinoma cells, consistent with a recurrence of the original tumour.

The right kidney showed evidence of long-standing hydronephrosis, but there was little evidence of chronic pyelonephritis.

DISCUSSION

Survival period following ureteric transplants for congenital defects were reviewed by Jacobs and Stirling (1951). In a study of the histories of 115 patients collected by questionnaire, they found that a survival time of five years or more could be expected in 76.6 per cent. of cases. They reported that 5 of these patients were still living ten years after operation.

Grey Turner (1943) reported 9 cases who were still living from sixteen to thirty years after operation for congenital defects with incontinence.

The unlucky occurrence of carcinoma in the region of the ureteric implants was probably coincidental and must be uncommon. Dixon and Weismann (1948) reported an instance of polyps of the sigmoid occurring thirty years after ureteric implantation for exstrophy of the bladder, but the polyps did not obstruct the ureters. They were able to find only one other probable case (Hammer, 1929).

SUMMARY

A woman aged 47 had a bilateral ureterosigmoidostomy at the age of 16 for congenital urinary incontinence. She survived in fair health for thirty years and died as the result of carcinomatous obstruction at the site of the ureteric implants in the colon.

ACKNOWLEDGEMENT

I wish to thank Mr. N. J. Bonnin for permission to publish this case.

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Books Reviewed

AN ANNOTATED BIBLIOGRAPHY OF THE HISTORY OF MEDICINE IN AUSTRALIA.

By BRYAN GANDEVIA, M.D., M.R.A.C.P. With a foreword by Sir GORDON GORDON-TAYOR, K.B.E., C.B., F.R.C.S., F.R.A.C.S. Monograph No 1 of the Federal Council of the British Medical Association in Australia. Sydney: Australian Medical Publishing Company, 1957. 9¼" x 7¼", 140 pp. Price: 35s.

This is an excellent and valuable reference work on the history of medicine in Australia. The historical contributions to the medical literature of a country are always scattered through many medical journals. These papers, essential to an historian for they form the framework for any research, are notoriously hard to locate. This tedious and sometimes frustrating search, so far as Australia is concerned, has been obviated by Dr. Gandevia's bibliography and historians owe him a great debt for the time, labour and skill that he has put into its production; he merits their warmest congratulations. He has collected together all these scattered references and provided them with critical annotations. The text is divided into 17 sections each covering a particular field of medical study ranging from the medical aspects of early exploration to aboriginal medicine. Author's names and subjects each have an exemplary index which include the annotations.

The biographical and autobiographical section is particularly valuable, for under the name of each medical pioneer is listed the book or papers written about his life.

This is a book which no library or medical historian can afford to be without; it is hoped that, in the course of time, appendices will be written at, say, five-year periods to keep it up to date.

The Federal Council of the British Medical Association have shown considerable foresight in selecting this admirable work as the first of their monographs.

LUMBAR PUNCTURE AND SPINAL ANALGESIA.

By Sir ROBERT MACINTOSH, M.A., D.M., F.R.C.S. (Edin.), F.F.A.R.C.S., M.D. (hon. causa), Buenos Aires and Aix-Marseilles; Hon. F.F.A.R.A.C.S. Second Edition. Edinburgh and London: E. & S. Livingstone Ltd., 1957. 8½" x 5½", 142 pp., 111 figures. Price: 25s. stg.

This is the second edition of this work, the first being published in 1951. Only small changes have been made in the text, notably in the sections dealing with the specific gravity of the cerebro-spinal fluid, and the risks of contaminated ampoules.

The subject of lumbar puncture is described in a clear manner. The technique of spinal analgesia detailed is that taught at Oxford and only passing references are made to other methods.

However, today, where spinal analgesia is used relatively infrequently, the description of a standard technique is of considerable value to the anaesthetist. This volume aims at reducing the incidence of complications to a minimum and should find a place on the book shelves of all who propose to use spinal analgesia.